THE

AMERICAN

JOURNAL OF SCIENCE.

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FOURTH SERIES.

VOL. XVIII—[WHOLE NUMBER, CLXVIII.]

WITH TWENTY PLATES.

NEW HAVEN, CONNECTICUT.

1904

THE TUTTLE, MOREHOUSE & TAYLOR COMPANY

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Number 108.

VOL. XVIII. JULY, 1904.

Established by BENJAMIN SILLIMAN in 1818.

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THE TUTTLE, MOREHOUSE & TAYLOR CO., PRINTERS, 123 TEMPLE STREET.

Published monthly. Six dollars per year, in advance. $6.40 to countries in the Postal Union. Remittances should be made either by money orders, registered letters, or bank checks (preferably on New York banks).

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[FOURTH SERIES.]

Art. I.—*Atmospheric Radio-activity*; by H. A. Bumstead.

It has recently been shown by a number of investigations, made in widely separated localities, that the radio-active gas obtained from the earth, from water, and from petroleum, has the same properties as the emanation from radium.* Some of the emanation must of course be present also in the air above-ground, and it is an immediate inference that the radio-active phenomena of the atmosphere may be due to its presence. Thus one might expect that the activity deposited upon a negatively-charged wire when it is exposed in the open air would decay at the same rate as the excited activity due to radium, and Elster and Geitel have recently made some measurements† which confirm this expectation, at least approximately. On the other hand, Rutherford and Allan,‡ who were the first to investigate carefully the rate of decay of the negatively-charged wire, obtained a different result; they found that the activity falls off regularly according to an exponential law and reaches half-value in about 45 minutes, whereas the radium-induced activity does not fall off exponentially during the first two hours, and, when it does begin to do so, its half-value time is 28 minutes instead of 45. Quite recently, Allan has made an extended study of atmospheric radio-activity§ in the course of which he has, in the main, confirmed the previous results obtained by Rutherford and himself with regard to the rate of decay, although certain observations point to the conclusion that the decay is not entirely regular.

* Adams, Phil. Mag., Nov. 1903; Elster and Geitel, Phys. Zeitschr., v, p. 11, 1904; Bumstead and Wheeler, this Journal, Feb. 1904; Himstedt, Drud. Ann., xiii, p. 573, 1904.

† Elster and Geitel, loc. cit.

‡ Rutherford and Allan, Phil. Mag., Dec. 1902.

§ Allan, Phil. Mag., Feb. 1904.

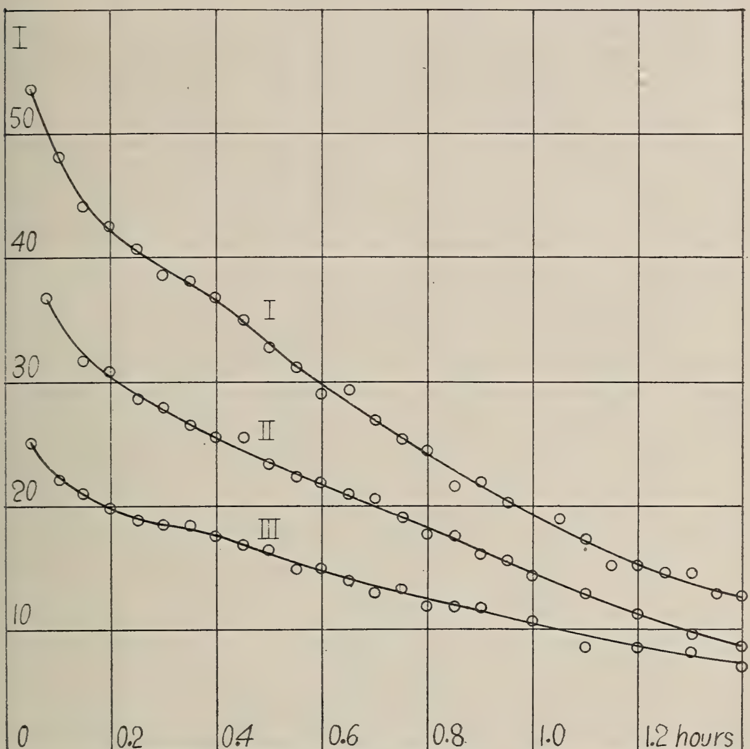
The experiments which I am about to describe were begun before the appearance of the recent papers by Elster and Geitel and by Allan, and were continued in view of the discrepancy between their results, and also because indications had been obtained of results not observed by either. A fine copper wire $\frac{1}{4}^{mm}$ in diameter was suspended horizontally, about 8 meters above the ground, between two neighboring buildings; it was attached to the negative pole of a Wimshurst machine, driven by a small motor, the positive pole of the Wimshurst being earthed. A parallel spark-gap 5^{mm} long served to keep the potential-difference constant during an exposure which was usually continued for three hours. The activity of the wire was observed in a cylindrical testing vessel, with the central rod connected to one pair of quadrants of an electrometer; the rod was protected by an earthed guard-plate in the usual manner. The bottom of the testing vessel was easily removable and bore four vertical brass rods just within the walls of the cylinder, and about these rods the exposed wire could be wound. The electrometer was of special construction, with sulphur insulation and adjustable quadrants; the needle was of silvered paper and the suspension a quartz fiber dipped in a solution of calcium chloride to render it conducting, as in Dolezalek's electrometer. With the suspension used and 90 volts on the needle, the sensitiveness was sufficient (250^{cm} per volt with the scale at one meter), and the instrument was very steady. When the potential on the needle was kept constant, the sensitiveness of the apparatus to a small sample of uranium oxide did not vary appreciably over a period of several days. Accidental motions of the needle were largely avoided by enclosing the connecting wire between electrometer and cylinder in an earthed brass box, outside of which a small electromagnet served to insulate or short circuit the quadrants.* The exposed wire could be put into the cylinder without disturbing the connections or jarring the electrometer, so that readings could be begun immediately; the only time lost after the end of the exposure was in taking in the wire and winding it about the frame. After the wire had been put into the testing vessel, measurements of the ionization current were made at intervals of three minutes during the first part of the experiment when the change in activity was rapid; later, readings were taken every six minutes.

In the earlier experiments, comparatively short wires were exposed (5 meters) and the decay of the activity of these could be followed with some accuracy for about two hours. The similarity to the behavior of the excited activity due to radium

* This arrangement has been previously described. This Journal, Feb. 1904, p. 100.

was unmistakable and is clearly shown in the curves plotted in fig. 1. The upper and lower curves, I and III, represent the decay of the activity of wires exposed in the open air on different days, while the curve between them, II, was obtained with a wire which had been exposed in a two-liter flask con-

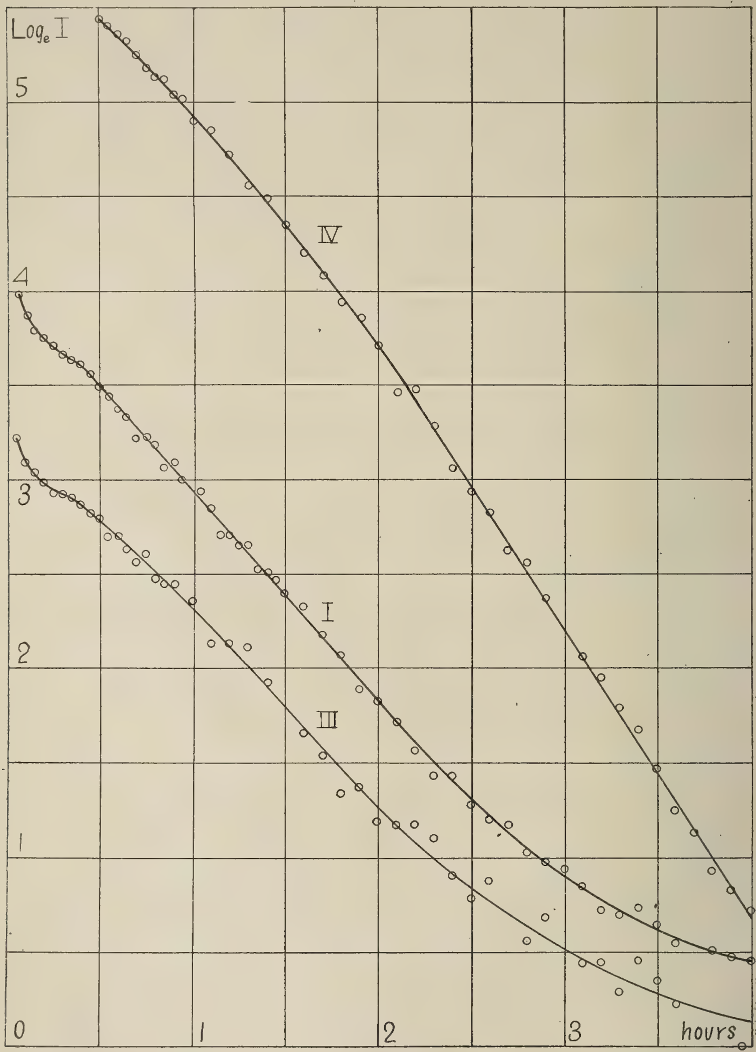
1



taining very weak radium emanation for the same time (3 hours), and charged to the same negative potential by means of the Wimshurst machine. The resemblance is obvious, especially in the initial rapid rate of decay, which is characteristic of the radium-excited activity, and which I have never failed to observe with the open-air wire when two or three observations were taken within the first ten minutes after the exposure ceased. When, however, the observations are carefully compared, it is evident that they do not entirely agree within the limits of experimental error; indeed a mere inspection of the curves in fig. 1 shows that, toward the end, the air wires were falling off at a slightly slower rate than the one exposed to radium emanation. It seemed probable that this

might be due to the presence of a small proportion of some form of activity decaying more slowly than that due to radium, and which would, therefore, show itself in a more and more

2



marked manner as time went on. Accordingly, wires 30 meters long were exposed in the same manner and observations carried on for four hours. The results of two such experiments are plotted in fig. 2, in which, for greater clearness, the nat-

ural logarithms of the ionization currents are plotted as ordinates, the time in hours being the abscissæ.* The curves I and III again represent the air wire, and curve IV a wire exposed to radium emanation, which is given for comparison. The existence of a slowly decaying activity is plainly shown by the curve between two and four hours. Twenty-four hours later, the wire was still appreciably radio-active, but the effect was too small to measure with accuracy; it was about one-fifth as active as at four hours.

In order to determine the rate of decay of this persistent activity, six lengths of wire were suspended in a wide zigzag between the second story windows of two buildings, the total length being 200 meters. They were allowed to sag from the horizontal by different amounts, so that their electrostatic fields should include as much of the surrounding air as possible. The small diameter of the wire made it possible to put this length into the testing vessel without difficulty. Nine hours after introducing it, the current through the cylinder was about six times that due to the "spontaneous ionization," of the air; and this, although small, was measurable with some degree of accuracy. Five observations were made at this time, and five more after an interval of 12 hours; combining them one by one, the following values of the coefficient of decay, λ, were obtained:

$$\begin{array}{r} 0{\cdot}069 \\ 0{\cdot}069 \\ 0{\cdot}066 \\ 0{\cdot}061 \\ 0{\cdot}073 \\ 0{\cdot}065 \\ \hline \lambda = 0{\cdot}067 \end{array}$$

The half-value time corresponding to this coefficient is $10\frac{1}{3}$ hours; and this is so near to the rate of decay of the excited activity due to thorium as to leave little doubt that the slowly decaying activity on the air wire is due to thorium. It is possible to increase the proportion of this to the more transient activity by prolonged exposure of the wire; for the radium-induced activity, an exposure of three hours is sufficient to practically reach the final equilibrium value, while the induced activity due to thorium will continue to increase for several days. By a twelve-hours exposure of a long wire, on a fine,

* On this diagram, radio-active substances which decay according to the same law will give parallel curves; if the law is exponential, the curve will be a straight line and the slope of the line will be equal to λ in the formula, $I = I_0 e^{-\lambda t}$. The zero of ordinates is a matter of indifference so that we may plot log I or (log I ± const.) as may be most convenient.

clear day, I have succeeded in collecting considerable quantities of this slowly decaying radio-activity. Eleven hours after the wire had been put into the testing cylinder, the current through the gas was 35 times that due to the spontaneous ionization and its gradual decay could be followed for several days. Observations extending over various intervals, from 6 hours to 27, showed that the decay was exponential and the average value of λ, from five determinations, was 0·0616, which indicates a decrease to half in 11·2 hours.

The observations upon the atmospheric activity can be accounted for fairly well, but not quite satisfactorily, by the assumption that it is entirely due to the excited activities of radium and thorium. In the following tables, the second column gives the calculated values of the ionization upon this assumption, the proportion of the two forms of activity being so chosen that the calculated and observed values shall agree at 1 hour and at 4 hours; for the present purpose, the decay of the thorium activity is assumed to be exponential (it is not actually so in the earlier stages) while the decay of the radium activity is found from Curve IV, fig. 2.* The third column gives the observed values for corresponding times, and the last column the differences between the calculated and observed values. The first table represents the experiments plotted in Curve I, fig. 2, the second, those plotted in Curve III.

CURVE I.

Assumed,

at 1 hour { Ra. activity = 17·0; Th. activity = 1·6

at 4 hours { Ra. activity = 0·244; Th. activity = 1·324

t (hours)	Calc.	Obs.	Diff.
1·0	18·6	18·6	0·00
1·5	11·1	10·8	+0·30
2·0	6·48	6·20	+0·28
2·5	3·81	3·69	+0·12
3·0	2·51	2·45	+0·06
3·5	1·89	1·84	+0·05
4·0	1·57	1·57	0·00

CURVE III.

Assumed,

at 1 hour { Ra. activity = 8·77; Th. activity = 1·23

at 4 hours { Ra. activity = 0·12; Th. activity = 1·02

t (hours)	Calc.	Obs.	Diff.
1·0	10·00	10·00	0·00
1·5	6·11	5·95	+0·16
2·0	3·73	3·53	+0·20
2·5	2·33	2·30	+0·03
3·0	1·67	1·67	0·00
3·5	1·32	1·32	0·00
4·0	1·14	1·14	0·00

* Up to 2·5 hours, this Curve IV, and other similar experiments which I have made, give a slightly different result from the empirical formula given by Curie and Danne (C. R., cxxxvi, p. 365, 1903) which is

$$I = I_0 \left[ae^{-\frac{t}{\theta_1}} - (a-1)e^{-\frac{t}{\theta_2}} \right]$$

where $a = 4·20$, $\theta_1 = 2420$ seconds, $\theta_2 = 1860$ seconds. This formula does not take into account the initial rapidly decaying activity due to radium. In the final, exponential part, my results are in close accord with those of Curie and Danne. The half-value time which they obtain is 27·9 minutes, while the value resulting from several experiments of my own is 27·7 minutes.

Although the differences are not large, they are apparently systematic and indicate that, between 1 and 2 hours, the air activity decays a little more rapidly than a combination of excited activities due to radium and thorium, while between 2 and 4 hours it decays more slowly. This cannot be due to the error committed in assuming the thorium activity to be decaying at its final rate; Rutherford has shown that, after a short exposure, thorium-excited activity at first increases so that a correction for this would be in the wrong direction. Another possible explanation of the discrepancy is that it may be due to an error in the determination of the curve for radium; a repetition of the determination, however, does not show any increase in the rate between 1 and 2 hours. If, therefore, we do not regard these differences as due to accidental errors (which seems unlikely in view of their apparent systematic character), they would seem to indicate the presence of a small proportion of some form of excited radio-activity decaying at a more rapid rate than that which the radium activity shows between 1 and 2 hours.* The present experiments are not sufficiently accurate to do more than indicate this as, to some extent, probable; but I am not without hope that it may be possible to go further in this direction by means of careful experiments especially directed to this end. The only other known induced activity, besides those due to radium and thorium, is that due to actinium. According to a recent determination by Debierne,† its decay is exponential and reaches half-value in 40 minutes. Its rate is, therefore, too slow to serve as an explanation of the discrepancy; but if a substance of more rapidly decaying activity is present, a small amount of actinium-excited activity is not impossible since there might be partial compensation between the two.

It is rather remarkable that, although the activity of the air wire is certainly due to a number of different forms of activity, decaying at different rates, the resultant effect between 0·5 and 2 hours is so nearly exponential, as indicated by the straightness of the lines in fig. 2. It is a further coincidence that, in this portion of the curve, the rate is so near the value found by Debierne for the excited activity due to actinium. The half-value time during this interval is, for Curve I, 38 minutes, for Curve III, 41 minutes. If the observations were not extended further, it would be a natural conclusion that the phenomenon was due to actinium emanation in the air. But the known presence of the thorium activity negatives the supposition that any considerable part of the effect can be due to

* Not necessarily more rapid than the final (half-value in 28 minutes) rate of the radium activity.

† Debierne, C. R., Feb. 5, 1904, p. 411.

actinium. The following tables will make this clear; they are like the two previously given except that, in the calculated column, it has been assumed that actinium and thorium activities are present instead of radium and thorium.

CURVE I.

Assumed,

at 1 hour { Actin. activity = 17·6; Th. activity = 0·96 }

at 4 hours { Actin. activity = 0·78; Th. activity = 0·79 }

t hours.	Calc.	Obs.	Diff.
1·0	18·6	18·6	0·00
1·5	11·4	10·8	+0·60
2·0	7·11	6·20	+0·91
2·5	4·56	3·69	+0·87
3·0	3·04	2·45	+0·59
3·5	2·12	1·84	+0·28
4·0	1·57	1·57	0·00

CURVE III.

Assumed,

at 1 hour { Actin. activity = 9·11; Th. activity = 0·89 }

at 4 hours { Actin. activity = 0·40; Th. activity = 0·74 }

t hours.	Calc.	Obs.	Diff.
1·0	10·00	10·00	0·00
1·5	6·27	5·95	+0·32
2·0	4·05	3·53	+0·52
2·5	2·72	2·30	+0·42
3·0	1·92	1·67	+0·25
3·5	1·43	1·32	+0·11
4·0	1·14	1·14	0·00

The differences are much larger than on the assumption of radium and thorium, and are quite beyond any possible experimental errors; and, to get even such an agreement, it is necessary to assume a smaller amount of thorium activity than the observations at later times than four hours will permit. Upon *a priori* grounds also, it is improbable that much of the effect can be due to actinium; the radium emanation is known to be present in the ground and decays so slowly (half-value in four days) that there is ample time for it to diffuse widely through the atmosphere; the actinium emanation, on the other hand, decays with great rapidity (half-value in four seconds),* and unless it were present in the ground in relatively enormous quantities, and not far from the surface, its effects in the open air could not predominate over those of the radium emanation. There is no reason to suppose that it does; any substitution of actinium for radium in the calculated values will cause them to depart more widely from the observed values. But, as previously remarked, if it should turn out that a small amount of a more rapidly decaying activity is present (as there is some reason to suspect), it is not impossible that some actinium activity may also be found. Mr. H. M. Dadourian, to whom I am indebted for assistance in many of the present experiments, is now engaged in an attempt to ascertain more definitely whether such an activity is present or not.

It will be observed that the general slope of Curve III is less rapid than that of Curve I, and that a considerably greater proportion of the thorium activity appears to be present. This, I think, may be accounted for from the known proper-

* Debierne, loc. cit.

ties of the radium and thorium emanations. The experiments plotted in I were made when the ground was hard frozen, and had been so (with occasional superficial thaws) for several months; III is the result of an exposure made a month later when the frost had entirely disappeared from the ground. The decay of the thorium emanation (half-value in one minute) is so rapid, compared with that of the radium emanation, that any delay in its liberation from the ground would considerably diminish the relative amount in the air. According to the accepted theory of radio-activity, due to J. J. Thomson and Rutherford, the disintegration of the gaseous emanation produces a solid material, responsible for the excited radio-activity, which, following Rutherford, we may call emanation X. The particles of emanation X produced by the gas (of either kind) before it leaves the ground would never reach the upper air, since they would not diffuse like the molecules of a gas but would be deposited in the soil; on the other hand, those produced after the escape of the gas would settle very slowly, on account of their small size, and might be carried considerable distances by currents of air. The view that the smaller proportion of thorium activity is due to the frozen condition of the ground, is supported by two other experiments (incomplete and therefore not given in detail), one made while the ground was frozen and the other when it was not; in the latter case the decay was noticeably slower, indicating a larger proportion of the thorium activity. The smaller total activity observed in III might be thought to negative the above explanation; I think, however, that it was due to another cause. There was a very perceptible haze in the air on the day when this experiment was made and little wind; the day of the other experiment was exceptionally clear and a good breeze was blowing. The wind would bring more of the particles of the emanation X within the electric field of the wire, and the fact that they were not loaded with drops of water (or with very small ones) would cause them to move with a greater velocity along the lines of force and hence a greater number might be captured by the wire, even if the number in a cubic centimeter of the air were actually less. The only exposure of a wire which I have made on a clear, windy day since the ground thawed, was one of twelve hours, so that the result is not comparable directly with the three-hour exposure; moreover, the total activity was not observed, but only the thorium effect remaining after ten hours. Reducing this to its value four hours after exposure ceased, taking account of the difference in the lengths of the wires, and assuming that the relation between the thorium activity and the time of exposure is

$$I_t = I\left(1 - e^{-\lambda t}\right),$$

the value obtained indicates that about 75 per cent more thorium activity would have been deposited on wires of equal lengths, in the same time, on the clear day when the ground was not frozen than upon the clear day when it was.

A similar explanation may be given of the fact that the radio-activity of rain and snow, discovered by C. T. R. Wilson, decays at a different rate from that of the negatively charged wire. Wilson finds that the former falls to half-value in about 30 minutes;* and this is very near to the final rate of the radium-excited activity. If we assume that some of the drops in the rain clouds are condensed upon the positively charged particles of radium emanation X present in the air, the time occupied by the drops in falling, and in the collection and evaporation of the water, would prevent the earlier, non-exponential decay of this activity from being observed; all that would remain would be the final, regularly decaying product. The absence of a noticeable amount of thorium activity may be explained by the rapid decay of the thorium emanation; although the particles of thorium emanation X, present near the ground may sometimes be carried to considerable heights by the wind, the proportion of radium activity must steadily increase as we go upward, since, in the case of the radium activity, we have not only the particles blown up from near the ground but also those produced by the radium emanation *in situ*; the slow decay of this emanation allowing it to diffuse to much greater heights than the thorium emanation. It is to be expected that a negatively charged wire suspended several hundred feet above the ground would show a smaller proportion of thorium than one exposed near the earth's surface.

I have also looked for evidence of the presence of the thorium and actinium emanations in the soil but, up to the present, without definite results. It is, of course, useless for this purpose to draw air from the ground and introduce it into an electroscope or condenser, as in testing for the radium emanation, on account of the rapid decay of the thorium and actinium emanations. A galvanized sheet-iron pipe 15^{cm} in diameter and 2 meters long, with open bottom, was sunk in the ground and a negatively charged wire suspended in it. The top was closed and a gentle current of air was drawn through the cylinder (entering at the open bottom from the ground) by means of a filter pump. The wire did not acquire sufficient radio-activity to enable one to follow its decay for more than two hours, and, even during this time, the ionization produced in the cylinder

* Proc. Camb. Phil. Soc., xii, p. 17 (1902).

was too small for accurate observations to be made. The rate appeared to be somewhat slower than that of the excited activity due to radium but no great confidence can be placed in the result. It is likely that a larger cavity in the ground would give more definite results but I have not yet been able to try this.

Conclusions.

1. The radio-activity acquired by a negatively charged wire exposed in the open air (at least as observed in New Haven) is mainly, if not wholly, due to the excited activities of radium and thorium. With a three-hour exposure, 3 to 5 per cent of the total initial effect is due to the thorium activity, the proportion depending apparently upon the greater or less ease with which the emanations escape from the soil. With a twelve-hour exposure the thorium activity is sometimes 15 per cent of the whole, and with a long wire, its decay may be followed for several days. There is some evidence that a small quantity of a more rapidly decaying activity is present in addition, but these experiments do not definitely establish this.

2. The radio-activity of rain and snow is probably due to radium-excited activity, the absence of the thorium effect being accounted for by the fact that the rapid decay of the thorium emanation prevents its reaching, in appreciable quantities, the height at which the rain-drops are formed.

Sheffield Scientific School of Yale University, April, 1904.

Art. II. — *Studies in the Cyperaceæ;* by Theo. Holm. XXII. The Cyperaceæ of the Chilliwack Valley, British Columbia (between lat. 49° and lat. 49° 10′; and long. 121° 25′ and long. 122°). (With figures in the text drawn from nature by the author.)

Through the courtesy of Mr. James M. Macoun, the writer has had an opportunity of examining a collection of *Cyperaceæ* which was made by him in the Chilliwack Valley during the summer of 1901, and upon which we take pleasure in presenting the following report. With the exception of *Scirpus Macounii* most of the others are old and well known species, but nevertheless of some interest from a geographical point of view, besides that, several of these represent types that have not hitherto been clearly accounted for, viz: *Carex scirpoidea*, *C. vulgaris* var. *lipocarpa*, *C. spectabilis*, etc.

I. Synopsis of the Species.

Carex.

Vignea.

Brachystachyæ nob.

Carex canescens L. Boggy spots, the lake (No. 26,651).

C. vitilis Fr. Swamps, the lake (No. 26,652) and among moss on rocks, 3,500 ft. alt. (No. 26,659).

C. arcta Boott. By marshes, Sumas Lake (No. 26,653).

Neurochlænæ nob.

C. nardina Fr. Crevices of rocks, 6,500 ft. alt., Tami Hy Mountain (No. 33,689).

Argyranthæ nob.

C. Deweyana Schw. Woods, the river (No. 26,644).

C. Deweyana Schw. var. *Bolanderi* Boott. Grassy slopes, 2,000 ft. alt. (No. 26,655); banks of streams, the river (No. 26,654); stumps by streams, the lake (No. 26,643).

Astrostachyæ nob.

C. interior Bail. Boggy marsh, east of the lake (No. 26,658).

C. læviculmis Meinshaus. Swampy places, the river (No. 26,657) and boggy spots, the lake (No. 26,656).

Stenorhynchæ nob.

C. stipata Muehl. Along ditches, near town (No. 33,736).

Phœnocarpæ nob.

C. teretiuscula Good. var. *ramosa* Boott. Marshes east of the lake (No. 33,743).

Athrostachyæ nob.

C. Crawfordii Fern. By ditches (No. 26,649).

C. festiva Dew. By rivulets, 5,500 ft. alt., Tami Hy Mt. (No. 26,646) and along the river at 4,000 ft. alt. (No. 26,645). (Fig. 1.)

C. festiva Dew. var. Gravel bars, the river (Nos. 26,647–48). (Fig. 5.)

Pterocarpæ nob.

C. Bebbii Olney. In mud by the river (No. 26,650).

CARICES GENUINÆ.

Melananthæ Drej.

C. Mertensii Prescott. By springs, the river (No. 33,670) and by rivulets, the lake (Nos. 33,671–72).

C. spectabilis Dew. Near melting snow, 5,000 ft. alt., Tami Hy Mt. (No. 33,659). (Fig. A.)

Microrhynchæ Drej.

C. vulgaris Fr. var. *lipocarpa* nob. By a rivulet, 4,000 ft. alt., the lake (No. 33,631) and by a pond, Tami Hy Mt. (No. 33,630).

C. dives nob. Marshes, the lake (No. 33,753).

Lejochlœnæ nob.

C. polytrichoides Muehl. Marshes, the lake (No. 33,660).

C. Hendersoni Bail. In thickets of *Alnus* and *Acer glabrum*, alluvial soil along the river (No. 33,657).

Athrochlœnæ nob.

C. nigricans Mey. Near melting snow, 5,000 ft. alt., Tami Hy Mt. (No. 33,705).

Stenocarpæ nob.

C. ablata Bail. Damp Banks, 4,000 ft. alt., the lake (No. 33,715).

Sphæridiophoræ Drej.

C. scirpoidea Michx. var. *stenochlœna* nob. By a rivulet, 4,000 ft. alt., the lake (No. 33,728). (Fig. 7.)

C. Rossii Boott. Rocky woods, the lake (No. 33,634) and on a snow-slide (No. 33,747).

Physocarpæ Drej.

C. utriculata Boott. Marshes east of the lake (No. 33,642).

Scirpeæ

Eleocharis ovata R. Br. (No. 34,772).
E. palustris R. Br. (No. 34,773).
Scirpus cæspitosus L. Alt. 3,500 ft. (No. 34,770).
S. Macounii nob. (No. 34,771). (Fig. 9.)
Eriophorum gracile Koch. (No. 34,769).
E. angustifolium Roth. Alt. 5,000 ft. (No. 34,768).

II. Notes on New or Little Known Species.

Carex vitilis Fries.

Several authors have generally confounded this well defined species with *C. brunnescens* (Pers.) Poir., known also as *C. Persoonii Sieber*, and *C. Gebhardi* Hoppe, furnishing a diagnosis which may be well suitable to both, but far from correct as to either. Both have been very clearly defined by Fries himself,* by Koch,† Blytt‡ and various others, and the distinctive characters may be drawn up as follows: The inflorescence of *C. vitilis* is composed of about five, remote, subglobose spikes with yellowish, spreading perigynia of which the beak is quite distinct and almost entire. In *C. Persoonii*, on the other hand, the spikes are oblong, brownish, and the perigynia are not spreading, but erect with a beak slit in its entire length on the outer, convex face. Both species are closely related to the frequent *C. canescens* L. but from which they are readily distinguished, however, by their color, as indicated, their slender culms and narrow leaves, and especially by the structure and position of the perigynium.

If this distinction be sufficient for considering *C. vitilis* and *C. Persoonii* valid species, a view which the writer feels most inclined to uphold, the latter, *C. Persoonii*, evidently does not occur on this continent, judging from the fact that we have never observed it in any of the large collections so far examined.

Carex festiva Dew.

Very few *Vigneæ* exhibit such pronounced ability to vary as is possessed by this species, and the plasticity becomes especially noticeable when we compare individuals from various stations from East to West: from Scandinavia to the Pacific slope, rather than from North to South or at different elevations in the mountains. For strange as it seems, several of the most characteristic deviations from the type often occur at the same altitude, from the subalpine to the high alpine regions, besides

* Fries, Elias: Novit. Floræ Suecicæ mantissæ, iii, p. 137.
Same: Summa veget. Scand., 1846, p. 223.
Same: Botan. Notiser, Lund., 1844, p. 23.
† Koch: Synopsis Floræ Germ. et Helvet., ii, 1857, p. 655.
‡ Blytt, M. N.: Norges Flora., i, 1861, p. 199.

that none of these seem restricted to certain northern or southern latitudes. On the other hand, the variation of *C. festiva* appears to be well marked in proportion to longitude, and it so happens that while the type seems to be equally dispersed from Alaska to Scandinavia, certain varieties are restricted to within the boundaries of the Pacific slope eastward to the Rocky Mountains, in other words, the species affords an excellent example of longitudinal variation, which we believe is a feature common to plants of southern origin in contrast to northern types.

Now in regard to the plant from Chilliwack Valley, and we refer especially to Nos. 26,645 and 46, this seems to represent the species as it is generally recognized, although the perigynium (fig. 1) is faintly several-nerved, and it must be borne in mind that Dewey makes no mention of such nervation in his diagnosis of the species:* "Spicis distigmaticis androgynis, superne pistilliferis subsenis ovatis in capitulum dense aggregatis; fructibus ovatis oblongis rostratis in apice serrulatis bifidis convexo-planis, squama ovata acutiuscula longioribus."

The specimens upon which the species was established came from "Bear Lake and the Rocky Mountains." However, all subsequent authors describe the perigynium as nerved on both faces, faintly or even prominently so, and Boott,† " who had authentic material at his disposal, did not hesitate to refer similar specimens with the perigynium "nervose" to this species of Dewey. And, so far, all individuals that have been examined and described exhibit such nervation to a more or less extent, a character that seems, besides, to be common to all the varieties known. It may be that the Chilliwack plant is nearer the type than any of the others on account of the perigynium being merely faintly few-nerved, but otherwise it is hardly different from the one figured as No. 2 on the same plate, taken from a specimen collected at Kananaskis in the Rocky Mountains of British Columbia. We might here call attention to the fact that the majority of specimens, generally recognized as typical, from this continent as well as from Greenland and Scandinavia exhibit the same nervation and outline of perigynium as the plant from Kananaskis (fig. 2). The habit of these specimens is exactly the same, furthermore the shape and color of the inflorescence is also similar. If we, on the other hand, examine some of the varieties, for instance "*decumbens*" (fig. 4), we observe a perigynium of much larger proportions and a habit, which is very distinct, and which, to some extent, may call to mind that of *Carex incurva Lightf.* In the var. *Haydeniana* (fig. 3) the perigynium shows the same nervation,

* This Journal, vol. xxix, 1836, p. 246.
† Illustr. of the genus *Carex*, vol. 1, p. 26.

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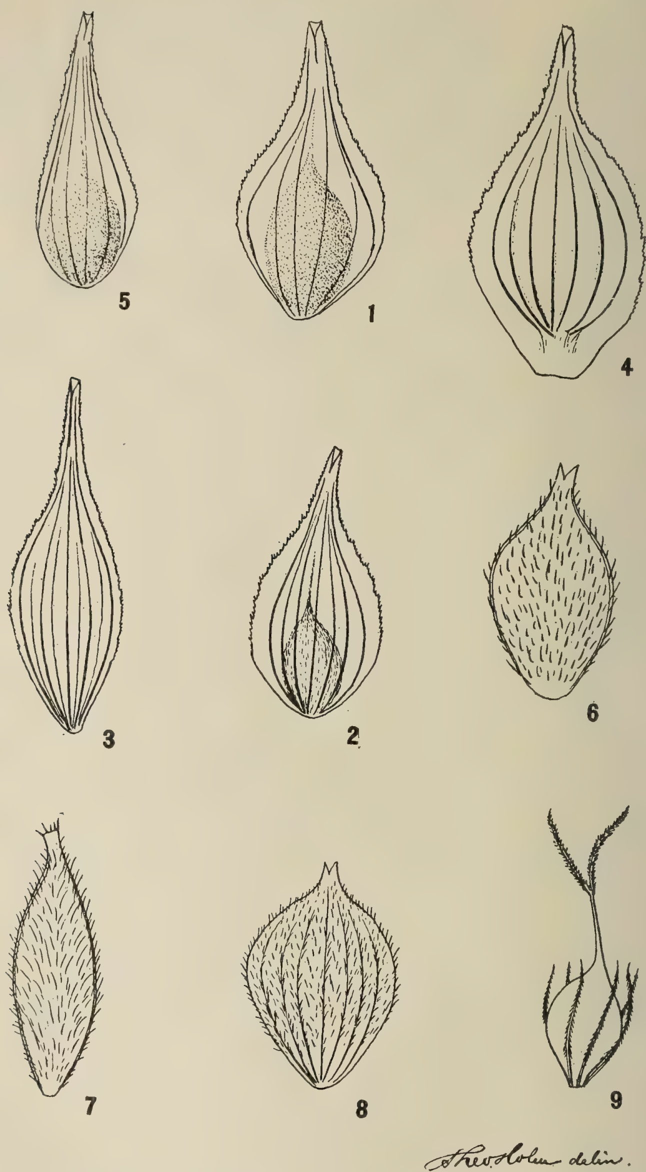


but the outline is very different, the body being very narrow and the beak relatively longer than in the typical plant, besides that the color of the spikes is very dark, almost black. Never-

theless, none of these varieties seem sufficiently characteristic for being considered as specifically distinct, inasmuch as many intergradating forms have been observed between these and the one which we consider typical.

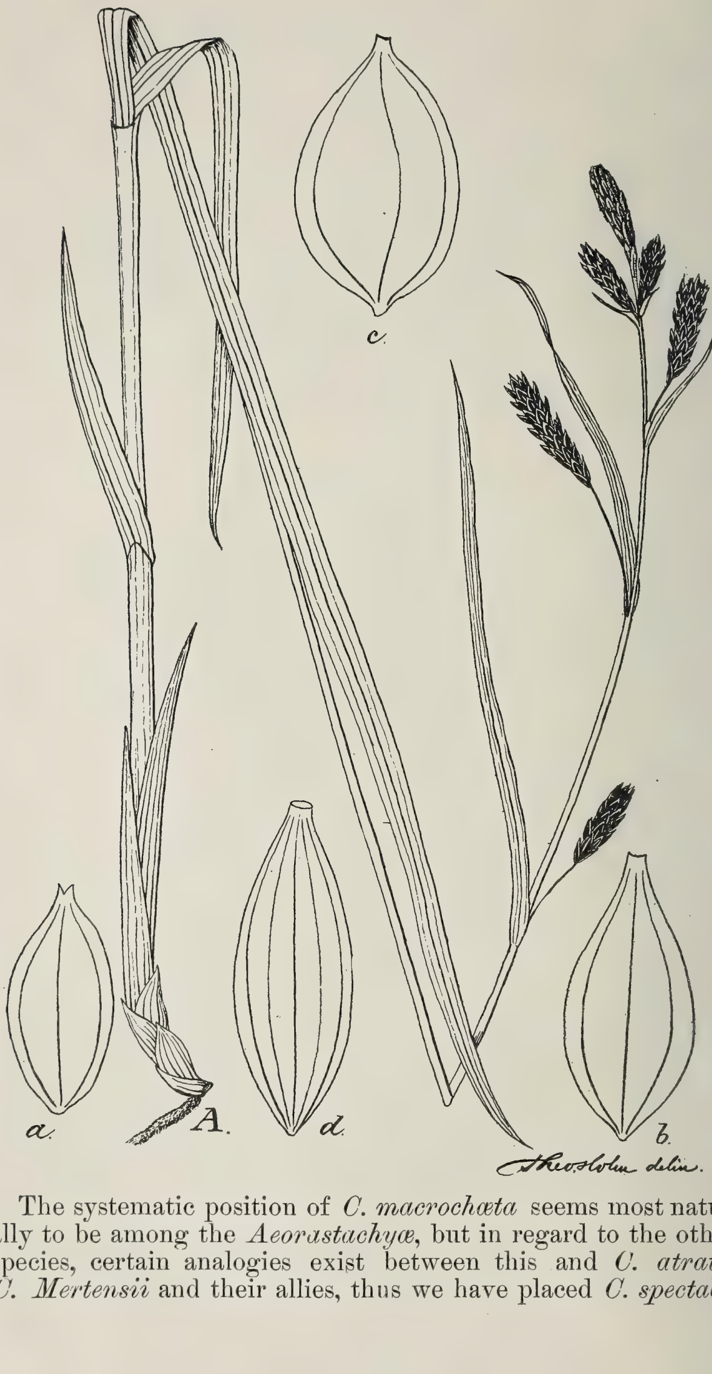
There is, still, another *Carex* from the Chilliwack Valley, which we are most inclined to refer to this same species, although its very slender culms and leaves, besides the conspicuously spreading perigynia, make it somewhat anomalous as *C. festiva*. Specimens of this plant (No. 26,647-48) were labeled *C. illota* Bailey by Mr. Macoun, and from their habit they are not unlike this species, which, however, is identical with Kunth's *C. Bonplandii* var. *angustifolia*. An examination of the perigynium (fig. 5) proved, however, that this does not show the structure of that of *C. Bonplandii*, but rather that of *C. festiva*, hence we prefer to enumerate it, at least "ad interim," as a variety of the latter.

Carex spectabilis Dew. (fig. A, p. 18.)

The original diagnosis* reads as follows: "Culm 8 to 12 inches high, erect, smooth, striate; leaves sheating, flat and smooth, upper ones about equalling the culms; bracts long and leafy; staminate spike single, erect, cylindric and oblong, with oblong obtusish scales; stigmas 3; pistillate spikes 2 to 3, ovate, cylindric, erect, remotish, pedunculate, and the lowest long-pedunculate, sheaths short; fruit ovate, obtuse nerved, scarcely rostrate, orifice two-lobed; pistillate scale oblong, lanceolate, short mucronate, all reddish brown, and a little longer than the fruit. Found in the Arctic regions."

Carex spectabilis in several respects is suggestive of *C. macrochæta* Mey., but differs constantly from this by its merely mucronate squamæ, the cylindrical and dense-flowered spikes, the two-lobed or simply emarginate orifice of the perigynium (figs. a, b and c), of which only three nerves are visible on the outer face. In *C. macrochæta* the scales are aristate, the midvein being very much extended beyond the apex of the scale, the spikes are relatively shorter and lax-flowered; furthermore, the perigynium is quite prominently several-nerved and the orifice entire (fig. d) and constantly so, judging from the numerous specimens which we have examined. But common to both are the aphyllopodic culms and distinctly pedunculate pistillate spikes, which, however, are often drooping in *C. macrochæta*, but merely spreading or erect in *C. spectabilis*. As to the color of the foliage, it appears as if the leaves and perigynia are deeper green in the latter.

* This Journal, vol. xxix, 1836, p. 248.



The systematic position of *C. macrochæta* seems most naturally to be among the *Aeorastachyæ*, but in regard to the other species, certain analogies exist between this and *C. atrata*, *C. Mertensii* and their allies, thus we have placed *C. spectabi-*

lis as the last member of the *Melananthæ*, showing transition to the former "grex" through *C. macrochæta*. The geographical distribution of *C. spectabilis* extends from the Chilliwack Valley south to California, but the species is evidently quite rare.

Carex vulgaris Fr. var. *lipocarpa* nob.

Most of the material of *C. vulgaris* secured from the Northwest belongs to this variety, and it is this plant which by recent American Caricographers has been identified as Boott's *C. decidua*. Mr. C. B. Clarke has called our attention to this mistake, and we owe to him the important information, that even if Boott at one time considered both of these identical, he, later on, corrected the determination in regard to the West American plant, and reserved the specific name *decidua* to the South American exclusively.

The diagnosis of *C. decidua* was published in Transacts. Linn. Soc. (vol. xx, 1845, p. 119), and the following points may be quoted as sufficient for distinguishing the species from varieties of *C. vulgaris:* "spicis 4–7 erectis; suprema mascula vel androgyna basi vel apice et basi mascula—perigyniis denticulato—serratis." It is no doubt a near ally of *C. vulgaris*, and perhaps more especially so of the variety *lipocarpa*, but even if the perigynia and the scales are deciduous in both, the characters enumerated above are not to be observed in this particular form of *C. vulgaris.*

Carex dives nob.

No. 33,753 of this collection was identified by Mr. Macoun as *C. variabilis* Bail. var. *elatior* Bail., but it differs in several essential points from this variety and can not be referred to *C. variabilis*. Habitually it is more like *C. Sitchensis* Presc., but the spikes are more numerous, more dense-flowered, the squamæ lack the characteristic spot at the apex, the perigynium is broader, prominently granular and often spinulose along the upper margins, hence we have identified the species as our *C. dives*, established upon a plant from Oregon, collected several years ago by Professor Henderson. The species is closely allied to *C. Sitchensis*, and may be placed near this and *C. acuta* of the *Microrhynchæ.*

Carex Hendersonii Bail.

This represents the Western and especially the Northwestern type of the higher developed *Lejochlænæ* of this continent, the others showing a decided Eastern distribution, for instance *C. laxiflora*, *C. plantaginea*, *C. digitalis*, etc. But among the lower forms, among those which we have enume-

rated as "hebetatæ," are some, which are also characteristic of the Western States, e. g., *C. Geyeri* and *C. multicaulis*, while *C. polytrichoides* is rare in that part of the continent, but abundant in the East, on the Atlantic slope.

Carex scirpoidea Michx.

The original diagnosis reads: "C. planifolia, dioica," spica unica, imbricato-cylindrica: capsulis dense pubescentibus, Hab. ad sinum Hudsonis."*

The first specimens known were thus monostachyous, but since then the species has been observed as being, and not very uncommonly so, distachyous: with a small, lateral spike, staminate in the staminate plant, pistillate in the pistillate, developed in the axil of a bract, which is always noticeable in a short distance below the terminal spike, as already mentioned by Drejer, who observed this peculiarity in Greenland specimens. The geographical distribution has been widely extended from Hudson Bay throughout the continent towards the Atlantic and Pacific slope, as far south as Colorado and California, besides that the species has been recorded from Greenland and even from the mountains of northern Norway, where it, however, seems to be very rare. It is very natural that a species, so widely dispersed, exhibits some variation, and as indicated in the enumeration of the species the Chilliwack plant deviates to some extent from the typical, the one from Hudson Bay, which is, also, the most commonly met with. We have, furthermore, noticed some peculiarities in the Californian plant, which seem to warrant the proposition of some varieties. The variation, however, seems confined to the structure of the utricle rather than to the relative size of the plant, its robustness, the outline of the spike, etc., characters that seem too variable to be depended upon in any species of the genus. The Chilliwack plant may be described as follows:

var. *stenochlæna* nob.

A very tall and slender plant with the pistillate spike clavate, loose flowered, especially at the base, the perigynium (fig. 7) longer and much narrower than in the type, spreading, very densely pubescent, with the orifice of the beak entire, ciliate; stigmata 3. Also collected in Alaska: Juneau and by Yes Bay.

var. *gigas* nob. (fig. 8).

Spikes mostly 2, very robust and dense-flowered; the number of bracts sometimes 3 (2 empty); perigynium broader than in the type, loosely pubescent and distinctly many-nerved, orifice of the beak as in the type, bidentate; stigmata 2 or 3,

* Michaux: Flora boreali-Americana, ii, 171.

the style not exserted. Only known from Siskyiou County, California: Mt. Eddy.*

Scirpus Macounii sp. n. (fig. 9).

Perennial with ascending shoots, the leaf-sheaths not fibrillose; basal leaves much shorter than the culm, flat, about 1^{cm} wide, the midrib distinct, very scabrous below, glabrous above, light green; cauline leaves with long sheaths; culm erect, triangular scabrous, leafy to about the middle, one meter in height, phyllopodic; inflorescence umbellate, decompound, the primary rays scabrous, from 1 to 7^{cm} in length subtended by long, foliaceous involucral bracts and small, tubular prophylla with or without a short setiform blade; secondary rays many but much shorter, only 1 to 3^{cm} in length, subtended by scale-like leaves and minute prophylla; spikes 3 to 6 together, sessile, cylindric, about half a centimeter in length; scales greenish brown, lanceolate, acuminate, the midrib stout and extended into a short mucro; setæ 6, straight, a little longer than the caryopsis, downwardly barbed to near the base; stamens 2, seldom 3; stigmata 2 or 3; caryopsis light brown, roundish in outline, compressed triangular in cross-section.

Evidently a near ally of *S. sylvaticus*, but in this the scales are obovate-oblong, slightly emarginate with a short mucro from the extended midrib, the stamens are only 2 in number, the setæ 4 and the stigmata nearly always 2, besides that the spikes are shorter and more oval.

III. The Geographical Distribution.

The *Cyperaceæ* of the Chilliwack Valley represent certain types of wide geographical range, some of which are arctic: *Carex nardina*, *festiva*, *scirpoidea*, *Eriophorum gracile* and *Scirpus cæspitosus*, while *Carex canescens* and *Eriophorum angustifolium* are even circumpolar. Some others are confined to this continent, but extend as far east as the Atlantic slope, for instance *Carex Bebbii*, *interior*, *Crawfordii*, *Deweyana*, *arcta*, *stipata*, *teretiuscula* and *polytrichoides*, while *C. læviculmis*, *Mertensii*, *spectabilis*, *vulgaris* var. *lipocarpa*, *dives*, *Hendersonii*, *nigricans*, *ablata* and *Rossii* are mostly western species, sometimes, however, extending eastward to the Rocky Mountains. *Eleocharis palustris* is cosmopolitan, and *E. ovata* is known from Middle Europe, Caucasus and Dahuria, besides from Australia.

Moreover, some of these species occur as alpine farther south,

* *C. pseudoscirpoidea* Rydberg has been described in the Flora of Montana (p. 78) as a segregate from *C. scirpoidea* Michx., but we find none of the characters sufficient for segregating the Montana plant from the type; moreover, the description is incorrect, for instance the perigynium is said to be "densely hirsute" instead of merely "pubescent," etc., besides that the name "Greek-Latin-Greek" is not admissible.

in Colorado: *Carex nardina* and *festiva*, while *C. Rossii*, *nigricans* and *scirpoidea* (the typical) are merely subalpine.

When we consider the *Cyperaceæ* of the Chilliwack Valley by themselves, they offer a strange commingling of types not only in regard to their distribution elsewhere, but, also, in respect to the types they represent. No doubt the flora of the valley has been influenced, and to a great extent, by the receding ice during the glacial epoch, when a number of plant-species moved north by way of the Rocky Mountains, but there is, also, some evidence of other species having reached this place in a much later period, for instance the eastern species.

It would be interesting to know how the geographical distribution compares with the other orders, and quite especially with those that contain types of the arctic or at least of the northern Flora, such as the *Saxifragaceæ*, *Ranunculaceæ*, *Juncaceæ* and *Gramineæ*. And in regard to the types, as we have seen these represented by the *Cyperaceæ*, it is somewhat strange to see so many *Vigneæ* in proportion to *Carices genuinæ* in a corner of the continent, where the latter usually appear to be predominating in species as well as in individuals; for the latter are really poorly represented, when compared with those of the Alaskan coast and Oregon. This seems the more remarkable when we notice that the *Scirpeæ* of the valley are the same, almost, as those of Alaska and vicinity.

As far as concerns the *Cyperaceæ*, the valley seems to have been a meeting-place of a number of species from remote localities and of remarkably specialized types, so utterly unlike each other. The magnificent collections and carefully drawn observations will, no doubt, enable Mr. Macoun to further illustrate the character, the composition and origin of this interesting vegetation.

EXPLANATION OF FIGURE I.

FIGURE 1.—Perigynium of *Carex festiva* (No. 26,646) Chilliwack Valley; magnified.
FIGURE 2.—Perigynium of *Carex festiva* from Kananaskis, Rocky Mts., B. C.
FIGURE 3.—Perigynium of same var. *Haydeniana* from Mt. Massive, Colorado.
FIGURE 4.—Perigynium of same var. *decumbens* from Pagosa peak, Colorado.
FIGURE 5.—Perigynium of same var. (No. 26,648) from Chilliwack Valley.
FIGURE 6.—Perigynium of *C. scirpoidea* (typical) from Montana.
FIGURE 7.—Perigynium of *C. scirpoidea* var. *stenochlæna* from Chilliwack Valley.
FIGURE 8.—Perigynium of *C. scirpoidea* var. *gigas* from Mt. Eddy, California.
FIGURE 9.—Caryopsis and setæ of *Scirpus Macounii* sp. n.

FIGURE II.

Carex spectabilis from Chilliwack Valley; natural size.

FIGURE *a*.—Perigynium of same, magnified.
FIGURE *b*.—Perigynium of same from Nevada County, California.
FIGURE *c*.—Perigynium of same from Kicking Horse Lake, B. C.
FIGURE *d*.—Perigynium of *C. macrochæta* from Alaska.

ART. III.—*Note on a New Permian Xiphosuran from Kansas;* by CHARLES E. BEECHER.*

THROUGH the courtesy of Mr. J. W. Beede, of Indiana University, the writer has had an opportunity to examine a portion of the cephalothorax of a large Xiphosuran from the Permian of Kansas. It apparently belongs to the genus *Prestwichia* and it is chiefly interesting, aside from its large size, on account of its coming from a higher horizon than any other American species yet known.

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FIGURE 1.—*Prestwichia signata* restored and of natural size. The smooth lateral or genal regions are the parts restored.

In the March number of the American Geologist for 1902, the writer described a species of *Prestwichia* from the Chemung (Devonian) of Pennsylvania, which carried the geological distribution of the genus from the Coal Measures to the Upper Devonian. The present species extends its range in the other direction as far as the lower Permian. The Carboniferous forms of *Prestwichia* in general show very little evidence of the segmental nature of the cephalothorax, and it was of considerable interest to describe in the Chemung species a series of nodes on each side of the glabellar region corresponding, it was believed, to five of the six pairs of appendages on the ventral side. The new Permian form also exhibits a similar series of appendicular lobes on each side of the axis, which agree in

* Among the papers of the late Professor Beecher was found the manuscript of this article as here printed. The manuscript was compared with the cast of the fossil and found to be complete as far as the very imperfect but interesting specimen will permit.—CHARLES SCHUCHERT.

position and form with the earlier species. It is also possible to detect an additional anterior pair, making the full number of six altogether.

Prestwichia signata, sp. nov. (figure 1).

A diagnosis of the species is necessarily quite incomplete, owing to the fact that thus far only a portion of the internal mold of a single cephalothorax has been discovered. It is believed, however, that the characters preserved will readily serve to identify the species, which is geologically quite important.

Cephalothorax large, depressed, convex, flattened on the dorsal side between the eyes, slightly arched in a longitudinal direction. The glabellar region is marked by a subconical elevation, angular along the median line, and terminating in front by a small, round ocellar node, distant from the anterior margin about one-sixth of the estimated length of the cephalothorax. Extending from the posterior margin of the cephalothorax are two low subangular ridges starting at points from the median line equal to the basal diameter of the glabellar cone, passing forward and curving slightly outward to the eyes, thence turning a little toward the axis and merging into the general contour before reaching the anterior end of the cone. The space thus enclosed on each side is occupied by five low rounded nodes, of which the posterior one is somewhat the larger and obliquely pointed behind. Just at the apex of the cone, and behind the ocellar node, is a pair of small transverse nodes, thus making six on each side. The second and third of each series are faintly delimited, while the fourth, fifth, and sixth are very clearly shown. The glabellar axis also shows extremely faint annulations corresponding to the lateral lobes. Opposite the third pair of lobes are the reniform or crescentic eyes, which are large and prominent for the genus. Two minute spots on each side of the small anterior median lobe, and distant from each other about $1{\cdot}5^{mm}$, indicate the ocelli.

The surface of the specimen represents a mold of the inner surface of the test, and is covered with a plexus of very slender anastomosing vascular furrows and ridges, much like those in the modern *Limulus*.

The cephalothorax as preserved has a length of 45^{mm}. The glabellar cone measures 33^{mm} in length and 18^{mm} across at the base. The outer edge of the eyes is about 20^{mm} distant from the median line and measures fully 5^{mm} in anteroposterior diameter.

Genal regions, abdomen, and telson unknown.

Horizon and Locality.—In the Fort Riley limestone of the lower Permian, three miles west of Stockdale, Kansas. The plastotype is in the Yale University Museum.

Laboratory of Paleontology, Yale University Museum,
New Haven, Connecticut, December 1, 1903.

Art. IV.—*Kunzite and its Unique Properties;* by Charles Baskerville and George F. Kunz.

In a recent investigation* made by us on the behavior of a large number of minerals and gems with various forms of radiant energy, including the emanations, as well as on the production of luminescence in some cases by other physical means, the new variety of spodumene, designated kunzite, was found to be peculiarly sensitive, and to exhibit some remarkable properties.

In general, as shown by these investigations, the gem-minerals were little affected by ultra-violet rays: but three species exhibited a high degree of responsiveness to these and to all forms of radio-activity, so far experimented with. These minerals were diamonds of certain kinds; willemite (zinc orthosilicate), which in some cases has been used as a gem-stone, and kunzite. The behavior of the last, as noted in various experiments, is unique and will be briefly described here by itself.

1. *Attrition and heat.*—Kunzite does not become luminous by attrition, or rubbing. Several specimens were held on a revolving buff cloth making 3000 revolutions per minute, so hot as to be almost unbearable to the hand, and still it failed to become luminous. Wollastonite, willemite and pectolite are, however, very tribo-luminescent.

As to luminescence induced by heat alone, it was found that kunzite does possess the property of thermo-luminescence to some extent, with an orange tint and at a low degree of heat.

2. *Electricity.* — The mineral assumes a static charge of electricity, like topaz, when rubbed with a woolen cloth. On exposing kunzite crystals of different sizes to the passage of an oscillating current obtained from large Helmholtz machines, the entire crystal glowed an orange-pink, temporarily losing the lilac color. A well-defined, brilliant line of light appeared through the center, apparently in the path of the current. On discontinuing the current, the crystal gave the appearance of a glowing coal. It was not hot, however, and the phosphorescence lasted for forty-five minutes.

Three large crystals, weighing 200, 300 and 400 grams each, were attached to copper wires so that the current passed in one instance from below up, and from the other upwards across the crystal—first across the prism, then parallel with the prism. In each instance the crystals became distinctively luminous, a pale orange-pink, and between the two wires a bright almost

* Science, N. S., xviii, 769, 1903.

transparent line passed from one wire to the other; in reality, as if the two elongated cones crossed each other, the line of the path being transparent at the sides, whereas the rest of the crystals appeared translucent. After the exposure of two minutes, they were laid upon photographic plates and in five minutes produced a fine auto-print, herewith shown. The crystals continued to glow for forty-five minutes.

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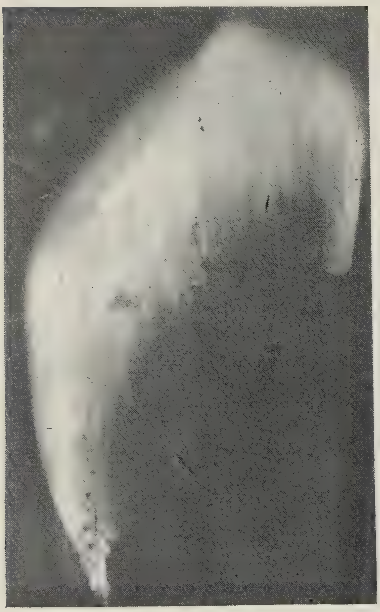

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FIGURE 1.—Self-print made by the exposure of crystal of kunzite to the Roentgen rays for five minutes. Note the frond-like emanations at the ends of the crystal.—Reduced one-half.

FIGURE 2.—Auto-print of crystal of kunzite luminescence induced by an oscillating current obtained from a Helmholtz machine.—Reduced one-half.

When a cut gem is suspended between the two poles, it becomes an intense orange-pink color, glowing with wonderful brilliancy. The discharge seemed as if it would tear the gem asunder, although actually it was unaffected.

3. *Ultra-violet rays.*—These invisible rays, produced by sparking a high voltage current between iron terminals, caused kunzite, white, pink or lilac, to phosphoresce for some minutes. The white responded most readily.

4. *Roentgen, or X-rays.*—All forms of kunzite become

strongly phosphorescent under these rays. An exposure of half a minute caused three cut gems to glow first a golden-pink, and then white for ten minutes. The glow was visible through two thicknesses of white paper, which was held over it. A large crystal excited for five minutes afterward affected a sensitive photographic plate.* Another crystal, exposed for ten minutes, was laid for five minutes on a sensitive plate.† The resulting auto-photograph was clear and distinct, but presented a very curious aspect not seen by the eye—as of a misty or feathery outflow from the side and termination of the crystal, suggesting an actual picture of the invisible lines of force. The other varieties of spodumene, mineral material and cut gems, failed to show this property. We are not yet in a position to offer a satisfactory explanation of the above.

Whereas kunzite is so responsive and fluorescent and so beautiful upon exposure to the X-rays, it is, however, like all silicates, opaque to the ray itself. Four crystals weighing 100, 200 and 400 grams each, were exposed to the Roentgen ray for two minutes. They became first a beautiful rose-orange, then assumed a white phosphorescence, and at the end of forty-five minutes there was still a faint residual glow. Two minutes exposure to the X-ray caused them to print a perfect auto-type (herewith shown, fig. 2). The glow in all instances showed first a rose-orange color, then a pale pink, finally resolving into a white fluorescence; the auto-print shows the feathery outlines of light or energy thrown out by the crystal.

5. *Conduct with radium preparations.*—Exposed for a few minutes to radium bromide with a radio-active strength of 300,000 (uranium being taken as unity), the mineral becomes wonderfully phosphorescent, the glow continuing persistently after the removal of the source of excitation. The bromide was confined in glass. Six hundred grams of kunzite crystals were thus excited with 127 milligrams of the radium bromide in five minutes. The effect is not produced instantaneously but is cumulative, and after a few moments exposure the mineral begins to glow, and its phosphorescence is pronounced after the removal of the radio-active body. The luminosity continued in the dark for some little time after the radium was taken away. No other varieties of spodumene examined, including hiddenite, gave like results. In this respect, as with the Roentgen rays, the kunzite variety stands by itself.

When pulverized kunzite is mixed with radium-barium chloride of 240 activity or carbonate of lower activity, the mixed powder becomes luminous and apparently remains so permanently; i. e., in several months no loss has been observed.

* Science, N. S., xviii, 303, 1903.

† This was made by Dr. H. G. Piffard of New York City.

The same is the case if pulverized wollastonite or pectolite be used instead of the kunzite. When either of these mixtures is put in a Bologna flask and laid on a heated metal plate (less than red-hot), the powder becomes incandescent and remains so for a long time after removal.

These three minerals phosphoresce by heat alone, as was mentioned above in regard to kunzite. Perhaps this luminosity of the mixed powders at the ordinary temperature may be accounted for in part by the evolution of heat* on the part of the radium compounds, but there are experimental reasons which cause us to reject such explanation for the total effect.

The *emanation* of radium, the α-rays, according to Rutherford† are condensed at a temperature of $-130°$ to $-140°$ C. The emanations were driven from radium chloride by heat and condensed with liquid air on a number of kunzite crystals, according to a method which will be described by one of us (B) and Lockhart in another paper, and *no phosphorescence observed.* Consequently *kunzite responds only to the γ-rays*, which are believed to be virtually Roentgen rays.

6. *Actinium.*—A sample of the still more rare and novel substance discoverd by Professor Debierne‡ and received from him through the courtesy of Professor Curie, was also tried as to its action upon kunzite and some other minerals. The actinium oxide, with an activity of 10,000 according to the uranium standard, gave off profuse emanations and affected diamonds, kunzite and willemite in a manner similar to the radium salts, with quite as much after-continuance. However, we have not tried the condensation of these emanations upon the minerals by refrigeration.

The peculiar properties of the kunzite variety of spodumene, which have been enumerated, have not been observed in any other of the gem or gem-minerals that we have examined. It is barely possible that the small amount of manganese may have much to do with it, but from our present knowledge basing a chemical explanation thereon is idle.

* P. Curie and Laborde, Comptes Rend., cxxxvi, 673.
† Phil. Mag., v, 561. ‡ Compt. Rend., cxxix, 593.

Art. V.—*Analysis of Kunzite;* by R. O. E. Davis.

At the request of Professor Charles Baskerville, Director of the Chemical Laboratory, I undertook the chemical analysis of kunzite, the new and beautiful variety of spodumene, described by Kunz and himself.* The methods used were those given in Hillebrand's excellent "Principles of Rock Analysis"† and need not be re-stated here.

A selected, clean, deep lilac-colored crystal, quite free from flaws, was ground to an impalpable powder and used in the analytical work. Following are the figures obtained:

	Percent.
SiO_2	64·05
Al_2O_3	27·30
NiO	0·06
MnO	0·11
ZnO	0·44
CaO	0·80
MgO	none
K_2O	0·06
Na_2O	0·30
Li_2O	6·88
Loss on ignition	0·15
Total	100·15

No chromium, vanadium, titanium, iron, strontium, barium, thorium, zirconium or phosphorus was found. On account of the unique properties possessed by the mineral the other rare earths were looked for. Dr. W. J. Humphreys, of the Rouss Physical Laboratory of the University of Virginia, kindly photographed the arc spectrum obtained from the material which had been freed from silicon and lithium. He reported none of the characteristic lines of cerium and yttrium groups present. The material lost its pink color on ignition.

University of North Carolina.

* See the preceding paper; also Science, xviii, 303 and 769, 1903.
† Bulletin of the U. S. Geological Survey, No. 176.

ART. VI.—*The Occurrence of Celestite near Syracuse, N. Y., and its Relation to the Vermicular Limestones of the Salina Epoch*;* by EDWARD H. KRAUS.

LAST summer, while conducting a field excursion with a class in geology from the Summer School of Syracuse University along the new Jamesville branch of the Syracuse and Suburban R. R., the mineral celestite was noticed. Although Dana† and Whitlock‡ mention Syracuse as a locality for celestite, I have been unable to find the original source§ for such a reference. Neither Cleveland‖ nor Beck¶ refer to Syracuse in this respect. This, therefore, is the first time that a detailed description of this occurrence of celestite is given.

This mineral was first found about three-quarters of a mile north of the village of Jamesville, near where the electric railroad crosses the turnpike to De Witt. At this point quite a heavy grade is encountered by the railroad and a considerable amount of rock—the drab limestone of the Salina epoch—had to be removed in order to allow the railroad to run parallel to the turnpike for about three-quarters of a mile. The cut varies from about two to six or eight feet in some places. In the rock which was removed, and also along the sides of the cut, the fresh mineral was found in a surprisingly large quantity.

The mineral does not occur in veins or cavities, as might be supposed and as is usually the case, but it is found disseminated throughout the rock. The character of the dissemination varies greatly with the locality and horizon in which the celestite is found. Three distinct types of dissemination were noticed. 1. In some cases the mineral has had ample time to assume well-defined crystal forms, which may in many instances be from one-half to one inch in length. This type of dissemination is shown by figs. 1 and 2. 2. In other places the crystallization was more rapid, and many crystals of a smaller but practically uniform size, one-eighth to three-eighths of an inch, resulted. Fig. 3 shows this type of dissemination;

* Read in abstract before the Onondaga Academy of Science, February 19, 1904.

† Dana, System of Mineralogy, 6th edition, 1892, 1063.

‡ Whitlock, New York Mineral Localities, New York State Museum Bulletin No. 70, 1903, 54.

§ Whitlock in a letter to me, concerning the mentioning of Syracuse as a locality for celestite by Dana, who is his authority, says: "It is possible that the notice of this locality was communicated by some local observer." This would, of course, account for the fact that nothing published can be found.

‖ Cleveland, Mineralogy, 1822.

¶ Beck, Mineralogy of New York, 1842.

the fresh mineral can be seen to the left. 3. The mineral may also occur disseminated not in the form of well-defined crystals but rather in small circular spots, which in some cases are about uniform in size, while in other instances

1 2

they may vary from three-sixteenths of an inch down to a needle-point. Figure 5 illustrates this occurrence of the mineral. No doubt the crystallization was so rapid that it was impossible for the mineral to assume well-defined forms.

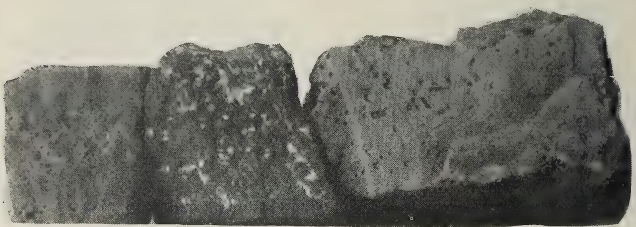
3

In the first two types of dissemination the orthorhombic character of the crystals is very easily recognized. The mineral is also characterized by a slight blue tint.

Numerous attempts were made to isolate crystals so as to make goniometric measurements. In every case, however, the crystal faces were dull and gave no reflections whatever. The

various faces could, nevertheless, by means of the cleavages parallel to the basal pinacoid and the unit prism, be determined with considerable accuracy. A very common combination of faces consists of the unit prism, *m* (110); macrodome, *d* (102); brachydome, *o* (011); and the brachypinacoid, *b* (010), and the basal pinacoid, *c* (001). This combination is a usual one with celestite.

4 5 6



The specific gravity of this celestite was determined by means of a Jolly balance of the Linebarger pattern. The mean of several determinations was found to be 3·958. This agrees very closely, indeed, with the normal specific gravity, 3·962, as given by Kopp.* The mineral not only conforms to the physical properties of celestite, but to the qualitative chemical as well. I shall report later as to the quantitative chemical composition.

As already indicated, the mineral was first found near where the electric railroad crosses the turnpike to De Witt. It occurs here in what Vanuxem calls the "Magnesium Deposit." Vanuxem† divides the Salina epoch into four divisions or deposits. He says: "The first or lowest deposit is the red shale, showing green spots at the upper part of the mass. Secondly, the lower gypseous shales, the lower part alternating with the red shales, which cease with this mass. Thirdly, the gypseous deposit, which embraces the great mass quarried for plaster, consisting of two ranges, between which are the hopper-shaped cavities, the "Vermicular Limerock" of Eaton, and other porous rocks. Fourthly and lastly, those rocks which show groups of needle-form cavities placed side by side, caused by the crystallization of sulphate of magnesium, and which may from that circumstance be called the 'Magnesium Deposit.'" The "Magnesium Deposit" is included in the "Gypseous Shales" of Luther.‡ The celestite is, however, not confined to the "Magnesium Deposit," for it was also observed in other localities in Vanuxem's "Third Deposit." I was subsequently

* Naumann-Zirkel, Elemente der Mineralogie, 13th Auflage, 1895, 549.
† Vanuxem, Natural History of New York, Third District, 1842, 95.
‡ Luther, Economic Geology of Onondaga County, 264.

able to observe celestite in many places southeast of Syracuse, principally, however, at Dunlop's quarry and in the vicinity of the Rock Cut on the D. L. & W. R. R. Later, Prof. T. C. Hopkins of Syracuse University noticed it near Split Rock in the drab limestones of the Salina along the cuttings of the new Auburn and Syracuse railroad. Although I was unable to make an exhaustive study last fall of its distribution, I do not doubt, whatever, but that its occurrence in the disseminated condition, as shown by the accompanying figures, is just as extensive in the limestones of the Salina elsewhere, as in the vicinity of Syracuse.

Beck in his "Mineralogy of New York"* says: "Celestite is usually associated with limestones, but that it does not seem to be peculiar to any geological epoch." He mentions but one occurrence in the dark Salina limestone, which is on the Owasco Outlet, near Auburn. Whether the mineral occurs in this locality disseminated throughout the rock, or in cavities and veins, neither Beck nor Whitlock† states with definiteness. From the general description which they give, one is led to believe that at this locality it is of secondary formation, that is, in veins or cavities. All the other occurrences in New York State which are mentioned by Beck and Whitlock (there are nine (9) of them) are in other epochs and without an exception secondary formations.

The occurrence at Dunlop's gypsum quarry, about one-half to three-quarters of a mile to the northeast of the locality where celestite was first found, is extremely interesting. It was impossible for me during my visits to this quarry to observe the rock containing the celestite *in situ* on account of the fact that the strata above the gypsum were for the most part covered with soil or other earthy material. The dump piles, however, contain a great many rock fragments, which show large quantities of the fresh mineral. The specimen shown in fig. 3 is from this locality. The crystals are rather small, one-eighth to three-eighths of an inch in length and, where the rocks have been exposed to the weathering agencies, the crystals on the outside have entirely disappeared, leaving very unique cavities. The cavities, nevertheless, betray by means of their distinct outline what the original material was, for the orthorhombic character as well as the various faces may be easily recognized. These cavities might at first sight appear to be bird tracks or something of that character, but as said, it can be easily shown that they are crystal cavities. That this is the case can be proven beyond a doubt by breaking the specimen, as has been done in fig. 3, and we find that the mineral is

* Page 210.

† Whitlock, New York Mineral Localities, 1903, 22.

still present in the interior—to the left--in well-defined crystals, while on the outside, as a result of leaching, only the crystal cavities are to be seen.

Several specimens from the first locality show very large cavities, and their resemblances to the impressions made by chisel points does not seem to be farfetched. Figs. 7 and 8 show such "impressions" or cavities on the outside, while in figs. 1 and 2 the fresh mineral can be seen in the interior of these same specimens. Cavities of this character were noticed by Eaton, Vanuxem and others, for Vanuxem* says: "Near

7 8

Syracuse, at the Hopper locality in Onondaga Valley, and at Chittenango and so forth, surfaces are seen which show an angular configuration, somewhat resembling those leaves whose ribs are straight, and incline at an angle of about 35° from the stem. These were first noticed by Prof. Eaton in his survey of the Erie Canal, having seen some which were thrown out in digging a well at Syracuse, the cause of which was rightly referred by him to crystallization."

Vanuxem further says: "On the canal, near Lake Sodom, layers of a similar kind but belonging to a lower deposit show numerous cavities not unlike those made by a small chisel of about three-quarters of an inch in width ; some of them single, and others cross each other as though struck at random. In the surface also of the calciferous slate above the gypseous deposit at Crill's in the town of Stark, there are small impressions in relief, the best defined of which are like obtuse Indian arrow heads, being triangular with their sides somewhat curved; these were previously noticed but not their forms." From this general description given by Vanuxem and also from the fact that Crill's farm in the town of Stark, Herkimer

* Vanuxem, Natural History of New York, Third District, 1842, 109.

County, is given as a locality for celestite by Beck and Whitlock, there is little doubt in my mind but that the investigators, mentioned above, had encountered specimens of the same character as those shown in figs. 7 and 8, and that the cavities and "impressions" were once filled by the mineral celestite, which was removed in the manner already referred to.

The third type of dissemination, referred to above, that is, in the form of small circular particles, as illustrated by fig. 5, is exceedingly instructive. When a rock which contains celestite in this form of dissemination is leached, it gives rise to a rock which appears as though it were worm-eaten. The lower portion of figure 5 shows the effect of such leaching and possesses a distinct porous structure. There is a very striking similarity between such a rock and the so-called "Vermicular Limestone" of Prof. Eaton and the older reports. This resemblance is shown very clearly in figs. 4, 5, 6; figs. 4, 6 being the so-called "Vermicular Limestone."

As regards the character of the rocks of the upper portion of the Salina, which contain the celestite, and which to some extent comprise the vermicular limestones, Luther* says: "The gypseous shales consist of fine-grained magnesium or dolomitic limestones in thin layers, masses of gypsum and gysiferous shale in two courses, separated by a bed of limestone forty to fifty feet thick. In the thicker and more compact layers of limestone, freshly broken blocks show the rock to be very dark, almost black in the interior, but after exposure the color changes to an ashen gray or medium dark drab, sometimes showing a slight pink shade. It is very much like hydraulic limestone in appearance, but the proportion of clayey admixture is so large as to injure or destroy its cohesive qualities. In the middle and lower beds it is frequently more or less porous or cellular. The cavities are sometimes an inch or more in diameter, very irregular and ragged in shape, and lined with a fine brown dust. When of this character, they are very unevenly distributed through the rock and most frequently are found on the surface of a layer or opening into a joint." (Compare with figs. 7, 8.)

"In other layers, the cavities are found to be much more numerous, occupying in the aggregate nearly one-half the space of the rock, and having the form of circular cells, with the diameter ranging from a quarter of an inch down to a needle-point. Usually the cells in a particular layer of limestone have a considerable degree of uniformity in shape and size, but occasionally the contrary is the case. They are smaller in the lower beds. *These cellular limestones are the 'Vermicular Limestones' of the older reports.*" See figs. 4 and 6.

* Luther, Economic Geology of Onondaga County, 264.

These "Vermicular Limestones" have given geologists much trouble as to a satisfactory explanation of their porous structure. Vanuxem speaks of the cause of their porous character in the following language: "The cells show that parts of the rock were disposed to separate into very thin layers, which project into the cells, an effect wholly at variance with aëriform cavities, whose removal caused the cells in question. This view appears to be fully confirmed by the discovery in this rock of those forms which are due to common salt, showing that a *soluble saline material* had existed in it, had acquired shape in the rock, and had subsequently been dissolved, leaving a cavity or cavities."* The discovery at Livonia, N. Y., of such a cellular rock filled with salt seems at first to support Vanuxem's theory to a very considerable extent. Of this rock filled with salt, Luther† says: "In the shaft sunk to the rock salt beds at Livonia, N. Y., at the depth of 1,396 feet, thirteen feet above the salt bed, a stratum of the cellular, magnesium limestone was reached, in which the cells were filled with salt. A large block was placed in a running brook, and in a few hours the salt had been dissolved out, leaving the rock in precisely the same condition that it presents when found in loose fragments or in the outcrops in this (Onondaga) County."

It seems almost impossible to conceive how the very soluble sodium chloride could be disseminated through a rock, as would be necessary to give rise to this peculiar porous structure of the "Vermicular" limestones, as is clearly illustrated by figs. 4 and 6. Certainly such a deposition of salt would not be in harmony with the now generally accepted theory of Ochsenius‡ as to the formation of salt deposits, as we find them in New York State, Stassfurt in Germany, and elsewhere. I believe that sodium chloride is an altogether too soluble salt to have been the original occupant of these many cavities of the "Vermicular Limestones."

According to Wackenroder,§ celestite is slowly, but completely, soluble in water containing sodium chloride in solution. Virck‖ says, that 100 parts of water containing 15·54 per cent of sodium chloride dissolve 0·2186 grams of strontium sulphate, which is the composition of celestite. The same authority says, that it is even more soluble in water containing magnesium chloride, and not quite so soluble in water containing calcium chloride.

* Vanuxem, Natural History of New York, Third District, 1842, 101.

† Luther, Economic Geology of Onondaga County, 1895, 265.

‡ C. Ochsenius, Die Bildung der Steinsalzlager und ihrer Mutterlaugensalze. Halle, 1877. Kemp, Handbook of Rocks, 1900, 78.

§ Comey, Dictionary of Chemical Solubilities, 1895, 455.

‖ Ibid., 1895, 455, also Chemisches Centralblatt, 1862, 402.

That many of the rocks of the gypseous shales contain, or did contain salt, is evidenced by what Luther* says: "In the beds of limestone lying between the principal gypsum deposits, and more abundantly in that underlying the gypsum beds, hopper-shaped mud casts of what are supposed to have been salt crystals are numerous. *They are found in both the cellular and non-cellular layers.*" The presence of the magnesium and calcium chlorides is easily proven by referring to the many excellent analyses of the brines of this state, as also to those of the salt manufactured from them. The following analyses† represent typical brines from the principal salt-producing sections of the state.

	Wyoming Valley	Genesee Valley	Onondaga.	
$CaSO_4$	0·3083	0·5790	0·3632	0·5440
$CaCl_2$	0·5268	0·4650	0·5701	0·1340
$MgCl_2$	0·1034	0·2125	0·2852	0·1790
NaCl	23·5819	25·3199	18·4277	18·0560
H_2O	75·4796	73·4234	80·3538	81·0870

Englehardt, Bishop and others‡ believe that the chlorides (magnesium and calcium) are derived from the rocks overlying the rock salt deposits. Englehardt thinks that the quantity of calcium sulphate is dependent upon the amount of these chlorides present.

These analyses show that the meteoric waters passing through the rocks of the upper portion of the Salina, since they contain sodium, magnesium, and calcium chlorides in solution, ought to, according to the authorities cited above, be good solvents of celestite. Then, if it be true that celestite can be quite readily dissolved in such a circulating water, it is not unreasonable to believe that strontium should be present in the brines of this vicinity.

Through the courtesy of Mr. John D. Pennock, chief chemist of the Solvay Process Co., Solvay, N. Y., I was able to procure a sample of the brine which that company obtains from its wells at Tully, N. Y., a short distance south of Syracuse. The brine is not formed by a true meteoric water, but according to Hazard,§ "fresh water is introduced into the wells, where it dissolves the salt, and is forced to the surface in the form of a saturated brine." It is, therefore, evident that such a brine would not show as large an amount of stron-

* Luther, Economic Geology of Onondaga County, 1895, 265.

† Merrill, Salt and Gypsum Industries of New York, State Museum Bulletin No. 11, 1893, Table of Analyses by Dr. F. E. Englehardt opposite page 38.

‡ Ibid., No. 11, 1893, 62.

§ Luther, Economic Geology of Onondaga County, 1895, 257.

tium as would be the case if the water were in contact with the limestones overlying the rock salt beds for a considerable length of time.

I am indebted to Professor F. A. Saunders of Syracuse University for a very careful spectroscopic examination of this Tully brine. The spark spectrum was produced by means of a Rowland concave grating, using a scale which was sufficient to give a visible spectrum of about fourteen inches. From the study of the negative of this spectrum, it was shown that all the characteristic lines of strontium were strongly developed, and clearly revealed the fact that strontium is actually present in this artificial brine in more than a spectroscopic trace. Not only is strontium present but a trace of barium was also noticed. After having communicated the fact that strontium is present in the Tully brine to Pennock, he was able to confirm Saunders's observation. Strontium is not indicated in the analyses of Englehardt, given above, on account of the fact that it was not tested for, and is, therefore, estimated with the calcium; hence the amount of $CaSO_4$ is necessarily a trifle too high. As to the amount of strontium, calculated as sulphate, present in the above brine, I shall report later. I have not been able, as yet, to examine the brines from the wells on the Onondaga Salt Reservation, which are formed by true meteoric waters, because the wells are shut down during the winter months.

With the following facts in mind, (1) that celestite is quite soluble in water containing sodium chloride, magnesium chloride or calcium chloride in solution, and (2) that the dissemination of celestite through the rock is not at all unlike that which would be necessary to form cavities as found in the "Vermicular" Limestones, (3) also that when such a rock has been leached the appearance of the resulting rock is exactly like that of these so-called "Vermiculars," and (4) that the brines of this vicinity do contain a considerable amount of strontium, also traces of barium, which is isomorphous with strontium and usually replaces it to a small extent in celestite, and (5) the finding in that "Vermicular," which outcrops in various places in Syracuse and vicinity, of cavities with such forms as would be produced by the leaching of celestite crystals,* we cannot but come to the conclusion *that these many cavities, now empty, in the "Vermicular Limestone" of the Salina Epoch must have once contained a mineral of the char-*

*The specimen of fig. 5, is from E. Adams St. near Irving Ave., Syracuse. A study of the cavities on the surface of this rock, which is locally known as "the vermicular," reveals those forms which are so characteristic of celestite. They are not unlike those of fig. 3, where the fresh material is still present in the interior.

acter of celestite, and that by the action of the agencies, mentioned above, the same was dissolved, leaving nothing but the so-called cells to show its former presence. I do not believe that the salt found in the rock in the shaft at Livonia, N. Y., is the original occupant of the cavities, but rather that it is of secondary formation, having been derived from the rocks above, which Luther says contain many mud casts at this locality. When the salt is leached from this rock, many of the resulting cavities show the characteristic outline of the celestite crystals and also possess that weathered appearance which is so peculiar to the cavities of the "Vermiculars."

During the coming summer I intend to continue my study of the distribution of the celestite-bearing limestones, and also the brines of the state as to the amount of strontium they contain. I will report as soon as possible.

In conclusion, I wish to thank my colleague, Mr. C. L. Hewitt, for the very valuable services he rendered in making possible the excellent illustrations which accompany this paper.

Syracuse High School, March, 1904.

Art. VII.—*A Famous Fossil Cycad;* by Lester F. Ward.

There is in the Museum of Mineralogy and Geology at Dresden a petrified trunk of a cycad that has been known for more than two centuries and a half. It is the type and only known specimen of *Cycadeoidea Reichenbachiana* (Göpp.) Cap. and Solms, the *Raumeria Reichenbachiana* of Göppert. It has the longest history of any specimen of its class, unless we count as history the thousand years or more that the type of *Cycadeoidea etrusca* lay upon an Etruscan tomb at Marzabotto before it was discovered by Count Gozzadini in 1867 and found its way in 1878 to the Geological Museum of Bologna.

When in 1894 I made a voyage to Europe chiefly for the purpose of studying the collections of fossil cycadean trunks in the various museums preparatory to the elaboration of those of America, I was not able to visit Dresden and see this specimen. In 1898 Dr. H. B. Geinitz sent me a photograph of it as it stood in the Dresden Museum resting on a wooden pedestal made to support it. This I reproduced in my memoir on the Cretaceous Formation of the Black Hills as indicated by the Fossils Plants,* explaining the circumstances in the text.† The photograph was not particularly clear and was of a light brown color, somewhat pale. The half-tone process by which it was reproduced brought out much that was latent in the photograph and the result is a considerably better view than the original. In studying this it was clear both that the petioles were descending and also that the sharp angle of the leaf scars was on their upper side, both of which features are very rare in cycad trunks. This raised the suspicion that the specimen might be inverted, and led me to remark in the footnote on page 605 of that memoir that, judging from the picture alone, "I should say that the trunk is here inverted, but to be certain it would be necessary to examine it. It is clear that in the present position the leaf scars have a decided downward direction, which is rare but not unknown (e. g., *C. Uhleri*). Moreover, the scars, which are subtriangular, have now their sharp angle upward, which, if the specimen is right side up, would indicate that the keel of the petioles was on the upper side, a condition which I have met with in only two other species, *C. aspera* and *C. insolita*."

On August 27, 1903, on my way from Vienna to Berlin, I stopped at Dresden and visited the Royal Museum. I readily found the specimen still standing upon the same support as when photographed by Dr. Geinitz. A glance at it was suffi-

* Nineteenth Ann. Rep. U. S. Geol. Surv., 1897–98, pl. lix.
† Ibid., pp. 601, 604, 605.

cient fully to justify the suspicion expressed in the above-quoted footnote, and it was clear that it stood on the somewhat even face presented by the transverse fracture through the middle of the trunk, while the much less even base, which, if the specimen had been placed in its natural position, would have required it to be supported by wedges or cement, was uppermost and distinctly showed its character as such. Dr. Johannes Victor Deichmüller, Directorial Assistant, who, in the temporary absence of the Director, was in charge of the Museum, and to whom I announced the object of my visit, was much interested in my account and kindly caused the specimen to be placed on a table where I could thoroughly examine all parts of it. I proceeded to describe it in my note-book, in which I systematically recorded all the visible features in the same manner as I have done for all the American trunks. As the specimen is regarded as constituting a species, and does, indeed, differ specifically from all others thus far known, these notes upon it form an adequate basis for the specific description. Before dealing with the systematic part, however, it will be of interest to give a somewhat detailed historical account of the specimen.

I. *History and Literature.*

Desiring to learn the authentic history of the discovery of this specimen and its removal to the Dresden Museum, I wrote to Dr. Deichmüller on my return to America, giving him such bibliographical references as I was able to find and requesting him to consult if possible the original publications. He was successful in finding the most important of the early documents, namely, the report of Christian Heinrich Eilenburg, who was the Director of the Dresden Museum at the time this specimen was acquired. It is printed in German and French and bears the following title:

Kürzer Entwurf der Königlichen Naturalienkammer zu Dresden. Dresden und Leipzig, in der Waltherischen Buchhandlung, 1755.

oder:

Description du Cabinet royal de Dresde touchant l'histoire naturelle. A Dresde et à Leipzig, chez George Conrad Walther, libraire du roi, 1755.

Dr. Deichmüller had the great kindness to copy out of this work and send me the following passages relating to the object under consideration:

"A large case in the sixth arcade contains petrifactions from the vegetable kingdom, which always fixes the attention of connoisseurs. That which is most admired here is a magnificent

block of petrifactions which M. Borlach, Counsellor of Mines, sent us from Poland. It weighs over 100 pounds, and is, in our opinion, only a mass of petrified Hippurites, or coral-cups, although a celebrated naturalist entertains the view that this superb mass may be the summit of a palm tree turned to stone." (P. 23 of the French and p. 24 of the German).

Dr. Deichmüller also found in the library of the Dresden Museum the original manuscript catalogue in Eilenburg's handwriting and never published, bearing the title: "Lithoxylorum seu lignorum petrefactorum varii generis variæque speciei Catalogus Novus in quo simul osteocollarum et lignorum fossilium præsens collectio indicata est a Christiano Henrico Eilenburgio, MDCCLIII." On page 41 of this catalogue occurs the following entry written in Latin: "No. 76. A segment certainly of petrified palm wood, the fibers and stems so distinct that they would be taken for combustible wood unless the contrary is shown by handling and weighing. A certain projecting knot surrounded by regularly arranged natural rows and fibers calls for special attention in this remarkable petrifaction; but the structure is the same above and below and such that we are able to see that it penetrates through the entire thickness of the trunk. From Poland."

The specimen was first figured by George Wolfgang Knorr in his well-known "Sammlung von Merkwürdigkeiten der Natur und Alterthümern des Erdbodens oder versteinte und andere gegrabene Cörper in illuminirten Kupfertafeln," of the text for which he only lived to write the first fascicle of 36 folio pages (Nürnberg, 1755). This did not include the description of this specimen. The remainder of the text was written by Johann Ernst Immanuel Walch, and published as a separate work with the title: Die Naturgeschichte der Versteinerungen zur Erläuterung der Knorrischen Sammlung von Merkwürdigkeiten der Natur, Nürnberg, Erster Theil, 1773, Zweyter Theil, Erster Abschnitt, 1768, Zweyter Abschnitt, 1769, Dritter Theil, 1771, Vierter Theil, 1773. This work is usually preceded by Knorr's fascicle and accompanied by the atlas as a separate volume, the whole being known as the work of Knorr and Walch. The plates of the atlas are numbered in an almost incomprehensible manner, but the figure occurs on Plate III*a* of the Supplement, which is really the 220th plate of the work, of which it is figure 6. No one who has seen the specimen would ever recognize this as being a figure of it, as it does not show either the shape or the markings at all correctly.

In Walch's description of it, which occurs on pages 150–152 of the third part, nothing is said of the defects of Knorr's figure, and he confines himself to a general treatment of the specimen. He quotes extensively from what he calls "Rath

Eulenburg's Beschreibung der Dresdner Naturalien-Cammer," especially, p. 24. This work is therefore apparently the same as that of which Dr. Deichmüller has furnished me the title, but it seems to contain much additional information relative to this specimen. From the account here given and from all other available sources we learn that the specimen was found in 1753 by a man named Schober in a swamp near Lednice, a small village in the salt region, about three miles E. S. E. of Wieliczka, in Galicia, and therefore only about fifteen miles in nearly the same direction from Cracow. This swamp is said to lie 500 feet above the level of a small stream, tributary of the Weichsel, which flows through that country within a mile of the spot. It was not, however, supposed that this swamp was the original source of the cycad, as there are no rocks near there and the formation consists of simple clay soil. It was supposed therefore that it had been brought there by the peasants who were accustomed to utilize the swamp in macerating their hemp. But there was said to be some higher ground not far distant where there are hard rocks, and where, in fact, a small piece was found resembling the cycad in structure. If so this is probably the source of the latter.

A mining engineer named Borlach in some way obtained possession of the specimen and sent it to Dresden, where it was placed in the Natural History Cabinet which has developed into the present Museum of Geology and Mineralogy, occupying the southwest portion of the Zwinger. Borlach left manuscript notes with the specimen giving most of the above-mentioned details and also indulging in some speculations as to the nature and significance of the specimen, which are tolerably free from the crudities of most of the discussions of his time relative to this class of objects. He queries, for example, whether it is a marine plant, or the nest of some marine animal, or a petrified land plant such as the top of a palm tree. He seems to incline to the last of these suppositions, but says that if it really be a petrified palm the climate must have been hot at the time it grew, from which he infers that the earth must have changed its axis since that time. It is probable that Borlach is the person to whose opinion to this effect Eilenburg refers in the passage quoted above from his report.

Eilenburg describes the specimen in considerable detail, says that it is irregularly broken at both ends, has a cylindrical but somewhat oval shape, is 22 inches in major and 20 inches in minor diameter and 24 inches high, is of a black color, though brownish at one end, has the hardness of agate or flint, and takes a fine polish. If a small piece be detached and thrown into the fire it becomes ash gray and gives off the odor of brimstone, but remains firm and does not burst like other hard

stones. He describes the surface of the specimen as covered with holes somewhat systematically arranged, sometimes in groups having the shape and size of a walnut, except that in some cases there rises in the middle on the longer side a rounded boss [this must refer to the reproductive organs]. The areolæ are described as oval and penetrating two to three inches into the stone, diminishing in size with the depth. But in some, he says, there is a nucleus [leaf base] of the same material as the rock, except that it possesses small longitudinal pores. Besides the larger cavities there are other much smaller ones of the size of a pea arranged in elliptical concentric groups, some of which are compressed [bract scars]. In some places are to be seen special growths, so to speak, having the form of buds which have not yet opened and only slightly project. Some of these smaller cavities have porous nuclei resembling grains of barley, but most of them are empty. In one spot on this rare petrifaction, he adds, a piece of the rock has fallen out leaving a funnel-shaped depression two to three inches deep, the sharp end being directed toward the axis.

Eilenburg, as we have seen, adopted the view that the petrifaction represented a hippurite or coral, but at that day these objects were referred to the vegetable kingdom.

On page 150 of Walch's work it is stated that the specimen was found in 1751, but on the next page it is said in Borlach's notes that it was found "erst in diesem Jahre." As all accounts agree that it was sent to Dresden by Borlach in 1753, this would also seem to be the date of its discovery. It is, however, possible that Borlach wrote these notes two years earlier.

Dr. Deichmüller finds a note appended to the entry above quoted in Eilenburg's manuscript catalogue, which reads as follows: "We take pleasure in referring in this connection to the able work of P. Gabr. Rzaczynsky: *Historia naturalis curiosa regni Poloniæ*, 1721, printed at Sandomir, where on pages 5–117, is to be found a more complete account of the petrified wood (*Lithoxylis*) discovered in Poland." From this entry Dr. Deichmüller thinks it not impossible that this specimen may be treated in Rzaczynsky's work as early as 1721. This does not seem probable from the above account, but it is greatly to be hoped that this work may be found and examined from this point of view.

The specimen lay in the Dresden Museum for nearly a century without receiving further attention. In 1844 Göppert seems to have already named and described it, for in his contribution to the second edition of Wimmer's Flora von Schlesien, vol. II, p. 217, where he describes the genus Raumeria and names *R. Schulziana* (found near Gleiwitz in Silesia), he adds a note in which he says that "the celebrated

cycadean trunk at Dresden belongs to the same genus (*Raumeria Reichenbachiana* Göpp. manuscript)." It was, however, nine years before the description and illustration appeared. Meantime Unger listed it in his Synopsis Plantarum Fossilium, 1845, p. 163, and in his Chloris Protogæa of about the same date, p. LXV. Göppert also put the name in his list contributed to Bronn's Handbuch (vol. II, Abth. II, Th. III, Index palaeontologicus, 1848), both in the Enumerator, p. 38, and the Nomenclator, p. 1078, referring it to the lower "Molasse" or Miocene. The naked name occurred at least four times more, viz., in Unger's Genera et Species Plantarum Fossilium, 1850, p. 301; in the same author's work: Die Pflanzenwelt der Jetztzeit in ihrer historischen Bedeutung, 1851, p. 230; in Massalongo's Conspectus Floræ Tertiariæ Orbis Primævi, 1852, p. 12; and in Giebel's work: Deutschlands Petrefacten, 1852, p. 91; before Göppert's descriptive paper: Ueber die gegenwärtigen Verhältnisse der Paläontologie in Schlesien so wie über fossile Cycadeen, in which the specimen was fully treated, finally appeared in the Jubiläums- Denkschrift der schlesischen Gesellschaft für vaterländische Cultur, Breslau, 1853, pp. 251–265, pl. vii–x.

In this paper we have a somewhat adequate description of the specimen accompanied by five figures (pl. viii, figs. 4–7; pl. ix), which, Göppert says, were furnished by Geinitz. He dedicates the species, however, to Reichenbach, long Director of the Dresden Museum, who, he says, had always afforded him free access to the collections. From this we must infer that he had studied the specimen himself at first hand. His historical account is very brief, referring chiefly to Walch's description, but making no mention of Eilenburg's.

He says that the trunk is cylindrical, 24 inches high, 20–22 inches in diameter, transformed into an entirely black, chert-like mass, showing very little structure. He classes it as the trunk of a cycad and compares it with that of *Cycas revoluta*, reproducing for comparison Vrolik's figure of a somewhat remarkable specimen of that species (pl. x, fig. 3). He also compares, or rather, contrasts it with *Cycadeoidea microphylla* of Buckland, reproducing (pl. x, fig. 2) his figure in the Bridgewater Treatise, vol. II, pl. lxi, fig. 1. He recognizes the scars as those of the petioles, and says some are from one to two inches deep. The prominent reproductive organs could not, of course, have failed to attract his attention, and he refers to them as the small scars that take the place of the large ones and arrange themselves in circular or elliptical groups, which he regarded as perhaps representing spots where buds are breaking through. Such buds, he says, really seem to have been present here. He seems to have no idea of their being

reproductive organs, and compares them with those of both *Cycadeoidea microphylla* and *Cycas revoluta*, saying that as the buds grow out branches are formed.

The principal figure of the trunk (pl. viii, fig. 4), furnished, as he says by Geinitz, represents, about one-eighth natural size, the side opposite to that shown in the photograph sent me by Geinitz. The specimen here stands more erect, and though inverted shows less of the base. Fig. 5, which Göppert calls the "obere Querschnitt," is a view of the base, and the structureless area on the upper left portion represents a large oblique fracture, which I described as the loss of a "large piece extending to the medulla and running out 28^{cm} above, with a width of 43^{cm}." Plate ix represents natural size an area 20^{cm} wide and 215^{mm} high near the base, which is still at the top of the figure, showing several of the larger reproductive organs, one of which, though here drawn as if the spadix had fallen out, is of special interest in showing a radiate structure with carpel-like partitions that may contain seeds.

Plate viii, figs. 6 (natural size) and 7 (somewhat enlarged) represent a cross section of a small piece from this trunk, apparently a leaf scar containing the base of a petiole, which Göppert says was sent him by Reichenbach at an earlier date, and which he seems to have cut transversely and figured himself. He recognizes resin ducts and parenchymatous cells, but finds no vascular bundles. I was myself unable to see any vascular bundles in the leaf bases. They are either indistinguishable from the parenchyma or else they lie close to the walls and blend with the partition lines.

In 1858 Geinitz issued one of the reports on the Dresden Museum which bear the title: Das Königliche Mineralogische Museum in Dresden, in which he gave a succinct history of the Museum from its earliest beginnings. It does not, however, contain any of the above facts relative to this specimen, which is only once mentioned (p. 17), in connection with the great three days' fire of 1849, during which the greater part of the collections thus far accumulated were destroyed. "Only one specimen, the precious *Raumeria Reichenbachi* Göppert, a cycad from Wieliczka, remained unscathed under the protection of a sandstone pillar."

The next mention that I find of this species is in Miquel's Prodromus Systematis Cycadearum, published at Utrecht and Amsterdam in 1861 (p. 29). It adds nothing to the knowledge of it.

Equally without significance is the allusion to it by Geinitz in his Dyas (Heft II, 1862, pp. 148, 341), except for his reference of it to the Permian, which was only a guess and of course a wrong one.

Carruthers in 1870 described the species twice in his well known paper on Cycadean Stems from the Secondary Rocks of Britain (Trans. Linn. Soc., vol. XXVI, pp. 682, 704), but does not appear to have seen the specimen. He says that the formation is unknown. Schimper also described the species in 1870 (Paléontologie Végétale, vol. II, p. 189), but he distinctly stated that he had not seen the fossil and could only copy Göppert's diagnosis.

Geinitz, in his report on the Dresden Museum bearing the same title as the one previously mentioned, but dated 1873, gives a short bibliography but, as it seems, inadvertently omits the title of Göppert's paper above treated, in which this specimen was first described. This omission he supplies by publishing a supplementary page dated January 12, 1874. This he was kind enough to send me at the same time as the photograph.

Count Solms-Laubach examined this trunk and was the first to point out that Göppert's whorls of small scars represent the lateral fruit-bearing axes (Einleitung in die Paläophytologie, Leipzig, 1887, p. 102). He did not therefore hesitate to class it as a Bennettites as Carruthers had defined that genus.

In 1892 Capellini and Solms-Laubach referred this species to Buckland's genus Cycadeoidea (I tronchi di Bennettitee dei Musei Italiani, Mem. Real. Accad. Sci. dell' Ist. di Bologna, Ser. V, Tom. II, p. 188), in which I have followed them in all my papers where I have had occasion to mention it (Proc. Biol. Soc. Washington, vol. IX, April 9, Washington, 1894, p. 85; Proc. U. S. Nat. Mus., vol. XXI, No. 1141, Washington, 1898, p. 198; Nineteenth Ann. Rep. U. S. Geol. Surv., 1897–98, Washington, 1899, pp. 601, 604, 605, pl. lix).

II. *Geological Position.*

It will be seen from the above sketch of the history of this specimen that the geological formation to which it belongs is only twice alluded to, one of the references placing it in the Miocene and the other in the Permian. That it could have come from neither of these formations I have all along been satisfied, and from its close resemblance to the trunks found in the Lower Cretaceous of other parts of Europe, and especially of America, I have believed that if its true source should ever be discovered it would be found to be in beds of that age. As it was found in territory now forming a part of the Austrian empire, and as geological activity in Austria has been very great for many years, I hoped to find that the region around Lednice had been surveyed in a manner sufficently thorough to furnish the data for forming a judgment as to the true age of the beds in which it occurred. After some unsuccessful search among the voluminous reports of the Austrian Geological Survey, I

finally wrote to Dr. Emil Tietze, the distinguished Director of the k.k. geologische Reichsanstalt, to learn if possible whether this district had been surveyed and if so where I could find the report, maps, etc., He replied promptly and informed me that he had himself made this survey and published the results in 1887.*

In my letter to Director Tietze, dated November 12, 1903, I said:

"I note that most of the region about Cracow is mapped as Tertiary. It does not seem probable that the specimen could have come from the Tertiary, as all similar trunks, from whatever part of the world, have been found in much older strata, ranging from the Middle Jurassic to the Lower Cretaceous. The specimens most closely related to it in America occur in the Lower Cretaceous of the Black Hills, South Dakota."

In his reply of December 10, he says:

"The salt formation of Wieliczka is certainly Tertiary and Miocene. The *Cycadeoidea Reichenbachiana* surely does not come from this salt formation, the flora of which is in fact known from the works of Unger and Stur. But at Lednice the beds of the Miocene salt formation do not occur. There are developed partly Oligocene, partly Lower Cretaceous deposits. Probably, therefore, the specimen in question came from the Lower Cretaceous of Lednice. Still, I must admit that thus far the presence of fossil plants was not known here, and also that in the general region about Wieliczka such remains have heretofore scarcely been found. This is of course no reason for doubting their presence at this locality."

A glance at the fourth sheet of Dr. Tietze's Map (Jahrb. 1887, pl. xix), shows that beds colored for Neocomian occur at Lednice and throughout that general region, and it seems therefore next to certain that it was from these beds that the specimen was primarily derived.

III. *Systematic Treatment.*

Description of the Species.

Cycadeoidea Reichenbachiana (Göpp.) Cap. and Solms.

1755. Hippuriten oder versteinerte Corallenbecher Eilenburg: Kürzer Entwurf der Königlichen Naturalienkammer zu Dresden, p. 24.

1771. Vegetabilische Versteinerung Walch: Die Naturgeschichte der Versteinerungen zur Erläuterung der Knorrischen Sammlung von Merkwürdigkeiten der Natur, Pt. III, p. 150; Atlas, Supplement, pl. III*a*, fig. 6.

* Die geognostischen Verhältnisse der Gegend von Krakau. Von Dr. Emil Tietze. Jahrb. d. k.k. Geol. Reichsanstalt, XXXVII. Bd., 1887, Wien, 1888, pp. 423-838. 4 maps.

1844. Raumeria Reichenbachiana Göppert in Wimmer: Flora von Schlesien, Ed. II, vol. II, p. 217 (nomen).
1853. Raumeria Reichenbachiana Göpp.: Jubiläums-Denkschrift d. Schles. Ges. f. vat. Cult., p. 262, pl. viii, figs. 4–7; pl. ix.
1892. Cycadeoidea Reichenbachiana (Göpp.) Cap. and Solms: Mem. Real. Accad. Sci. Ist. Bologna, Ser. V, Tom. II, p. 188.
1894. Cycadeoidea Reichenbachiana (Göpp.) Cap. and Solms. Ward: Proc. Biol. Soc. Washington, vol. IX, p. 85.
1899. Cycadeoidea Reichenbachiana (Göpp.) Cap. and Solms. Ward: Nineteenth Ann. Rep. U. S. Geol. Surv., 1897–98, pp. 601, 604, pl. lix.

Trunks large, cylindrical or subconical, little compressed, the longer diameter 54^{cm} at the base and 52^{cm} near the middle, the shorter 44^{cm} at the base and 42^{cm} near the middle, unbranched; rock very hard and chert-like, black, becoming light gray on long exposed surfaces, fine-grained, breaking with a conchoidal fracture, of high specific gravity; organs of the armor all slightly and uniformly ascending; phyllotaxy much interrupted and irregular but consisting of two spiral rows of which those from left to right form an angle of about 45°, and those from right to left of about 25° or 30° with the axis, the former much more clear; leaf scars subrhombic, the lower angle obtuse, the two upper sides commonly reduced to a curve or arch, somewhat uniform in size, averaging 25^{mm} in width (but showing extremes ranging from 15^{mm} to 30^{mm}) and 13^{mm} in height showing extremes from 10^{mm} to 20^{mm}; leaf bases usually visible at the bottom of deep areolæ, the depth varying from 2^{cm} to 6^{cm}, probably all disarticulated at a natural joint, the somewhat spongy or porous interior inclosed in a sheath of firm, fine grained material which itself consists of two plates, the two together about $0{\cdot}5^{mm}$ thick; vascular bundles invisible, perhaps inclosed between the two plates of the sheath; walls very thick but varying from 2^{mm} to 15^{mm}, averaging about 1^{cm}, rough and irregularly grooved on the outer surface, sometimes showing a median line, often traversed by bract scars; reproductive organs very large, numerous and prominent, distorting the arrangement of the leaf scars, elliptical in cross section, the longer axis often 7^{cm} or 8^{cm}, the shorter 4^{cm} or 5^{cm}, but varying greatly in size and sometimes appearing to coalesce; involucral bract scars numerous and conspicuous, covering most of the surface of the trunk, spirally arranged around the spadices but straggling out over the surface of the walls, semilunar, triangular or subrhombic, rather small (3^{mm} to 6^{mm} long, 1^{mm} to 3^{mm} wide); central portion of the inflorescences often covered with scars or markings, sometimes solid and raised 1^{cm} to 2^{cm} above the general surface, a few concave and showing a radiate

carpellary structure suggesting the presence of contained seeds; armor very thick (5^{cm} to 10^{cm}), its attachment to the axis obscure and apparently indefinite; woody cylinder about 8^{cm} thick, uniform in color and texture and showing on the rough fractures no subdivisions or rings; medulla about 13^{cm} in diameter and nearly circular in cross section, hard, black, and homogeneous in structure, which differs little in appearance from that of the wood.

The only specimen of this species known is the one in the Dresden Museum of which the history is here recorded. It consists of the basal portion of a very large trunk of unknown height and of which the exact form of the upper part is also of course unknown, but from analogy with the hundreds of specimens of cycads which are now known from different parts of the world, it is tolerably safe to infer that the specimen represents at least half the length and that the top was conical or dome-shaped. The fracture through the middle portion is a little oblique so that the specimen leans somewhat. It is nearly even, but not wholly so, the central part of the piece preserved being somewhat higher than the part next to the surface so as to make it slightly arched or convex in the middle, sloping gently away from the center in all directions, the elevation amounting to about 4^{cm} or 5^{cm}. The specimen seems to have always been placed on this square end, apparently for no better reason than that it would thus stand without having to be blocked up, as would have been necessary if it stood on its much less even base. The base, as shown by the figures, is imperfect from the loss of numerous chips and splinters on one side and of the large piece on the other to which mention has already been made (supra, p. 46).

The specimen has not been weighed so far as known unless this was done soon after it was sent to Dresden, and if so the exact weight was not recorded, the only reference to the weight being that of Eilenburg who says that it is "über einen Centner schwer" (ibid, p. 24), which is repeated by Walch (op. cit., p. 150). This estimate was certainly much too small, whether we make the Centner 100, 112, or 120 pounds. The specific gravity is about the same as that of the type specimen of *C. Jenneyana* and it is somewhat larger than the basal piece of that specimen, which weighs 95·26 kilograms, or nearly 210 pounds.

Of all the species known to me *C. Jenneyana* is the one that *C. Reichenbachiana* most closely resembles, but as the above description clearly shows, it is certainly distinct from that species and is probably distinct from all other species thus far described.

After having taken full notes of the specimen, from which I have been able to make the above description, I drew the spe-

cial attention of Professor Deichmüller to the most promising of the reproductive organs, and at my indication he marked several of these with red chalk. Should any one ever undertake the study of its internal structure these should be specially investigated. Of course I cannot promise that they would be found to contain seeds, but if there are any that contain them the ones so marked are likely to do so.

It is unfortunate that Count Solms was unable to make this investigation when he was studying the British and Italian trunks. In a letter that I received from him dated October 28, 1894, he said:

Cycadeoidea Reichenbachiana (Göpp.) Cap. and Solms.
Dresden Mineralogical and Geological Museum.

"It is to be regretted that at the time I requested it and offered to pay the expenses of transportation and section cutting, permission to investigate the great *Raumeria Reichenbachiana* of the Dresden Museum was not granted me. Now that I am through with this work I would not expend the necessary three or four hundred marks. From the examination of a couple of small splinters broken from it I know, however, that the trunk presents well-preserved areas, and it contains a mass of inflorescences which are certainly wholly included. Geinitz has also sent me the photograph."

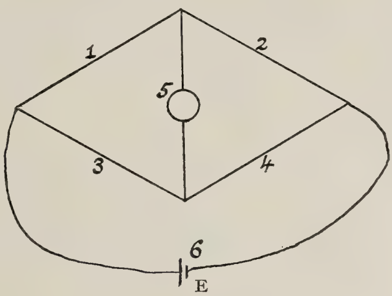
It is greatly to be hoped that Count Solms may be induced to return to this subject and to investigate thoroughly the celebrated Dresden cycad from the standpoint of its internal structure and its botanical affinities.

As the specimen has thus far always been figured inverted, I have undertaken in the figure on the preceding page to show it standing on its base. But having nothing but the reproduction of the photograph sent me by Geinitz, all that can be done is to invert this and reproduce it again. I have already stated that as it stands on the support in the Dresden Museum it leans somewhat on account of the fracture being slightly oblique to the axis. This it is sought to remedy also, and the present figure shows it erect with the scars horizontal and their acute angle downwards, as it undoubtedly grew. As the light was from above in the photograph it is of course from below in this figure, but this mechanical defect is less pronounced than it would be in most cases.

ART. VIII.—*A Comparison of Two Ways of Using the Galvanometer*; by HENRY A. PERKINS.

THERE are a number of instances in laboratory practice where a galvanometer is used to record changes in the resistance of a piece of apparatus such as a bolometer, selenium cell or bismuth spiral where the highest degree of sensitiveness is required, and there is a choice between a Wheatstone Bridge arrangement and a simple series connection. The purpose of this paper is to investigate the relative delicacy of the two methods.

In using the Wheatstone Bridge the variable resistance is introduced in one of the arms, the bridge is balanced and the galvanometer then deflects when the variable arm changes.



In order to calculate the current that will flow through the galvanometer, we apply Kirchhoff's laws, and assume the various resistances equal to r_1, r_2, r_3, r_4, r_5 and r_6, where r_6 is the resistance of the battery, r_5 that of the galvanometer and the others represent the arms of the bridge, r_1 being the variable resistance.

In calculating the galvanometer current we shall make use of the following six equations:

$$
\begin{aligned}
&(1)\quad C_1 = C_2 + C_5 \\
&(2)\quad C_3 = C_4 - C_5 \\
&(3)\quad C = C_2 + C_4 \\
&(4)\quad E = C r_6 + C_1 r_1 + C_2 r_3 \\
&(5)\quad O = C_1 r_1 - C_3 r_3 + C_5 r_5 \\
&(6)\quad O = C_2 r_2 - C_4 r_4 - C_5 r_5
\end{aligned}
$$

Combining and assembling the coefficients we obtain

$$
\begin{aligned}
&C_2(r_1 + r_2 + r_6) + C_4 r_6 + r_1 r_6 = E \\
&C_2 r_1 - C_4 r_3 + C_5 (r_1 + r_3 + r_5) = O \\
&C_2 r_2 - C_1 r_4 - C_5 r_5 = O
\end{aligned}
$$

Solving for C_5 by determinants

$$
C_5 = \frac{E\,(r_3 r_2 - r_1 r_4)}{\sum_1^6 r_a r_b r_c - r_1 r_2 r_5 - r_1 r_3 r_6 - r_2 r_4 r_6 - r_3 r_4 r_5}
$$

Since r_1 is the variable branch $\frac{dC_5}{dr_1}$ is the measure of the sensitiveness of the arrangement. This differential reduces to

$$-\mathrm{E}/\{2r_1r_6 + 2r_5r_1 + r_3r_6 + r_5r_6 + r_1r_3 + r_1r_4 + r_1^2 + (r_1^2r_6 + r_1r_5r_6 + r_1^2r_4 + r_1r_4r_5)/r_3 + (r_3r_5r_6 + r_1r_3r_5 + r_1r_5r_6)/r_4\}$$

when r_2 has been eliminated by the relation $r_1r_4 = r_2r_3$ which is true when the bridge is balanced.

In this equation r_3 and r_4 are independent variables, and it is now essential to find how they should be adjusted to render $\frac{dC_5}{dr_1}$ a maximum. Assuming r_3 constant and differentiating the above coefficient with respect to r_4 and setting it equal to O we obtain a value of r_4 which must be substituted in $\frac{dC_5}{dr_1}$ and the result again differentiated with respect to the one remaining variable, r_3. Finally solving for r_3 and making use of $r_1 r_4 = r_2 r_3$ and the value already obtained for r_4 we have r_2, r_3 and r_4 in terms of the constants r_1 r_5 and r_6. These values are

$$r_2 = \sqrt{\frac{(r_1 + r_6)\, r_5 r_1}{r_1 + r_5}} \qquad r_3 = \sqrt{\frac{(r_1 + r_5)\, r_1 r_6}{r_1 + r_6}} \qquad r_4 = \sqrt{r_5\, r_6}\,*$$

We are now in a condition to evaluate the sensitiveness of the bridge method by substituting the values of r_2 r_3 r_4 in the coefficient of sensitiveness, reducing it to

$$\frac{dC_5}{dr_1} = \frac{-\mathrm{E}}{r_1\{2r_5 + 2r_5^{1/2}\sqrt{(r_1 + r_5)} + r_1\}} = \mathrm{S}_1$$

where r_6 has been set equal to O, as in either method considered it will be small compared to the other resistances, and if it is retained the above expression is too unwieldy for ready comparison with that which follows.

The second case is much simpler. Here the battery, variable resistance and galvanometer are arranged in series. Assuming here also that the battery resistance is negligible, and also using the same E.M.F. we have

$$\mathrm{C} = \frac{\mathrm{E}}{r_1 + r_5} \text{ and } \frac{d\mathrm{C}}{dr_1} = -\frac{\mathrm{E}}{(r_1 + r_5)^2} = \mathrm{S}_2.$$

* Heavyside obtained almost the same results in the fourth paper, Vol. I. Electrical papers, but his value for r_2 is clearly wrong. It should read $\sqrt{\frac{gx(x+f)}{g+x}}$ instead of $\sqrt{\frac{gx(g+f)}{g+x}}$, as can be readily shown by applying the bridge formula to the values of r_3 and r_4 and solving for r_2. Moreover, the value of the differential coefficient $\frac{dC_5}{dr_1}$ was not given, as his method was essentially different from the one just outlined, so his paper was of little assistance.

To compare S_1 and S_2, the most obvious method is to find what conditions render them equal. Setting $S_1 = S_2$ we have $r_5^3 - 4r_1^2 r_5 - 4r_1^3 = O$. The solution of this cubic gives $r_5 = 2{\cdot}4\, r_1$, approximately. A further comparison indicates that if the galvanometer resistance is less than 2·4 times that of the cell, the series arrangement is best, although when the galvanometer resistance is zero they are again equal. All values of r_5 greater than $2{\cdot}4\, r_1$ give S_1 greater than S_2, and when $r_5 = 6r_1$ the bridge method is twice as sensitive.

The following table gives an approximate idea of the relative value of the methods. E is assumed = 100 and $r_1 = 1$. The values are given to the nearest integer.

r_5	S_2	S_1
O	100	100
r_1	25	17
$2r_1$	11	10
$3r_1$	6	7
$4r_1$	4	6
$5r_1$	3	5
$6r_1$	2	4
$7r_1$	1·6	3·4

Another aspect of the problem arises when a certain maximum current through the variable resistance is admissible. Let this current = K. Then in case of the bridge method $K = \dfrac{E}{r_1 + r_2}$ substituting for E in S_1 we have $S_1 = \dfrac{2K}{3r_1 + 4r_5}$ very nearly. In order to obtain this simple value it was assumed that in all cases where the current through r_1 arm of the bridge is limited, r_1 will be considerably smaller than r_5; and even if r_1 is half as large as r_5, the error is still very small.

Now S_2 under these conditions $= \dfrac{K}{r_5 + r_1}$ hence it is clear that the series method is always best when the current in r_1 must not rise above K.

One more case remains; when the allowable current through the galvanometer is less than that allowed through the variable resistance. In this case S_1 becomes equal to S_2 when $\dfrac{K'}{K} = \dfrac{2(r_5 + r_1)}{4r_5 + 3r_1}$ when K' is the maximum current allowed through the galvanometer. If $\dfrac{K'}{K}$ is smaller than this, the bridge method is clearly best. When K' is very small indeed as compared to K this method is vastly more sensitive than the other.

Trinity College, May, 1904.

Art. IX.—*Further Work with the Rotating Cathode;* by H. E. Medway.

[Contributions from the Kent Chemical Laboratory of Yale University.—CXXVIII.]

It has been shown in a previous article* that metals may be precipitated electrolytically, with great economy of time and with much exactness, by the use of a rapidly rotating cathode. The apparatus employed consists of a platinum crucible fastened to the vertical shaft of a small electric motor and dipping into the solution to be electrolyzed. A current from a series of storage batteries is passed through the solution between a platinum anode and the crucible, which serves as the cathode, while in rapid rotation; it being found that under these conditions a high density of current may be used with a consequent shortening of time over that required for complete deposition with a stationary cathode.

In the article referred to, attention is called to the rapid determination of copper, silver and nickel electrolytically. It is the purpose of the present article to give results, obtained in the same way, in a study of the conditions adapted to the use of the apparatus upon solutions in common use in the ordinary process of electrolysis between stationary electrodes, and in some cases studied by Exner† with reference to the application of the stirring anode and ordinary cathode to similar rapid precipitations.

Cadmium.

Cadmium sulphate, approximately 0·2 grm., was dissolved in 50 cm^3 of water, 10 drops of dilute sulphuric acid added to give conductivity and the solution was electrolyzed, while the crucible, serving as the cathode, was rotating at a rate of 650–700 revolutions a minute. It was noticed that a perceptible solvent action of the acid takes place upon the deposit of cadmium in the short time necessarily taken to remove the crucible from the liquid. Therefore, in order to avoid siphoning, dilute ammonia was added drop by drop after the metal had been all deposited and while the current still passed, until the solution was faintly alkaline.

That this procedure proves satisfactory, the following results will show:

*Gooch and Medway: This Jour., xv, 320, 1903.
†Jour. Am. Chem. Soc., xxv, 896.

Cadmium taken grm.	Cadmium found grm.	Error grm.	Current Amp.	N. D. 100.	Time. min.
0·1088	0·1083	−0·0005	2	6·6	15
0·1088	0·1085	−0·0003	2	6·6	15
0·1088	0·1092	+0·0004	1·5	5·	15
0·1088	0·1090	+0·0002	2	6·6	15
0·1088	0·1093	+0·0005	1·5	5·	12
0·1088	0·1093	+0·0005	2	6·6	10
0·1088	0·1087	−0·0001	2	6·6	10

Tin.

For the purpose of trying the electrolytic deposition of tin, a solution of stannous ammonium chloride was prepared of about 20 cm³ volume. To this was added a cold saturated solution of ammonium oxalate amounting to 100 cm³. The electrolysis then proceeded in the usual way.

Results are below:

	Tin taken grm.	Tin found grm.	Error grm.	Current Amp.	N. D. 100.	Time. min.
1)	0·0804	0·0802	−0·0002	2·5	8·3	20
2)	0·0804	0·0800	−0·0004	2	6·6	20
3)	0·1607	0·1610	+0·0003	2·5	8·3	20
4)	0·1607	0·1603	−0·0004	2·5	8·3	20
5)	0·1607	0·1607	±0·0000	3·5	11·6	15

An alkaline oxalate was also used in the case of zinc — the next metal whose precipitation was attempted, but it was found expedient to use potassium oxalate instead of ammonium oxalate, since the presence of ammonium salts appeared to retard the complete deposition of the metal. Therefore, the following procedure was adopted: The zinc salt—preferably the sulphate—was dissolved in 50 cm³ of water and 4 grms. of potassium oxalate were added. The solution was then submitted to electrolysis.

The results follow:

	Zinc taken grm.	Zinc found grm.	Error grm.	Current Amp.	N. D. 100.	Time. min.
1)	0·0553	0·0556	+0·0003	2·5	8·3	25
2)	0·0553	0·0553	±0·0000	2·5	8·3	25
3)	0·0553	0·0552	−0·0001	2·5	8·3	25
4)	0·0993	0·0995	+0·0002	2·5	8·3	30
5)	0·0993	0·0994	+0·0001	2·	6·6	25
6)	0·0993	0·0991	−0·0002	2·	6·6	25

In the usual method of electrolysis with stationary electrodes, it has been found that, when the attempt is made to remove the zinc from the platinum upon which it has been deposited, there is a coating of platinum black, some of the zinc presumably having amalgamated with the platinum. Only by dissolving the zinc, heating the crucible to redness and finally making another application of acid can this black coating be conveniently removed, there being a loss of platinum due to this removal. In order to avoid this formation it has been found necessary to coat the platinum with copper and deposit the zinc upon this. The zinc and copper may then be easily removed together by acid.

In depositing the zinc upon a rotating cathode it was found to be unnecessary to coat the platinum with copper, since the zinc could be removed without any appearance of platinum black, thus avoiding the second treatment by acid, with the attendant loss of platinum.

Gold.

The apparatus was next applied to the determination of gold. A solution of auric chloride was made of 25 cm^3 volume. Potassium cyanide was then added in considerable excess and about 30 drops of strong ammonia. The electrolysis was carried on in the usual manner.

The results are given below :

Gold taken grm.	Gold found grm.	Error grm.	Current Amp.	N. D. 100.	Time. min.
0·0695	0·0694	−0·0001	2·	6·6	30
0·0695	0·0696	+0·0001	2·	6·6	30
0·0598	0·0598	±0·0000	0·5	1·8	30
0·0598	0·0598	±0·0000	0·5	1·8	30
0·0598	0·05975	−0·00005	1·	3·3	25

No attempt was made to find the minimum time required for these depositions.

ART. X.—*On the Transverse Vibrations of Helical Springs;* by HOWARD L. BRONSON.

IT has been known for a long time that the pitch of a stretched india-rubber cord rises very little, if at all, when its length is increased by stretching. This peculiarity has been recently investigated by T. J. Baker* and by Viktor v. Lang.† Both found that the apparent constancy in pitch is in some way related to the fact that the length and tension are linearly related through a considerable range.

Now if a linear relation between length and tension is the only requisite for constancy of pitch, then certainly a helical spring ought also to have a constant pitch for a considerable change in length. This consideration, together with the fact that a metal spring ought to be more uniform in its behavior than a rubber cord, were the two things which suggested this study of helical springs.

Apparatus.

The first thing necessary for the investigation was to find suitable springs, which should have considerable range in size and stiffness. Seven springs were made of brass wire which seemed to have sufficient regularity and the desired range of size. The following table gives for each spring the diameter of wire used, the diameter of the mandrel on which it was wound, its mass, and L′, the approximate percentage increase in length for an increase in tension of ten grams.

TABLE I.

	Diam. of Wire.	Diam. of Mandrel.	Mass.	L′.
Spring 1	0·29 mm.	1·80 mm.	1·283 gr.	13
Spring 2	0·29	3·18	1·298	50
Spring 3	0·42	3·18	2·210	9
Spring 4	0·46	3·18	3·769	5
Spring 5	0·46	5·18	6·058	20
Spring 6	0·91	5·94	24·750	1
Spring 7	0·46	5·94	6·536	30

The relation between the length and tension was obtained with the spring hung in a vertical position, the lengths being read directly from a mirror scale.

The accurate determination of the frequency was the most difficult part of the work, but very consistent results were finally obtained by the use of a chronograph. The time was furnished by a clock with a seconds pendulum, which was arranged to make one contact every complete vibration. These two-second intervals were very uniform, and a comparison with the Yale

*Phil. Mag., vol. xlix. †Wied. Ann., vol. lxviii.

Observatory clock showed that the rate of the clock used was entirely negligible for the purpose in hand.

Figures 1, 2 and 3 show the arrangement of the apparatus for holding the spring and starting the vibrations. MN, fig. 1, is the base about 40 inches long and $1\frac{1}{4}$ inches thick. On the

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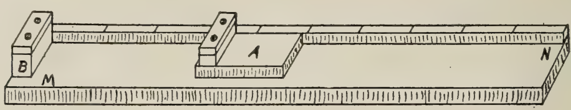

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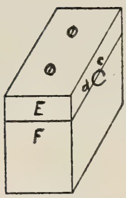

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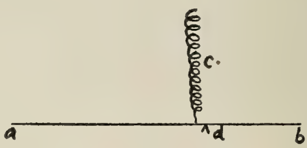

back of this is a metre scale, from which the lengths of the spring were read directly. One end of the spring was clamped to the fixed block B, the other to the movable block A.

It was found quite difficult to clamp the ends of the springs in any manner which did not have an appreciable effect on the frequency. The method finally adopted is shown in fig. 2. The last turn of the spring was drawn close up to the block by means of two fine wires fastened at *c* and *d*, which are the extremities of its horizontal diameter. These two wires were then clamped between the blocks E and F, and held the spring very firmly, yet with very little constraint.

A fine wire fastened to the center of the spring made contact with a mercury cup at each vibration. The chronograph was adjusted delicately enough to record signals with frequency as high as thirty-five per second.

In order to have uniformity in the amplitude of the vibrations, it was found convenient to use an apparatus of which fig. 3 is a diagrammatical sketch. *a b* is a wooden arm about 9 inches long pivoted at *a*; *d* is a stop which can be adjusted so that the end *b* will start the spring vibrating with the desired amplitude; the spring *c* is strong enough to release the spring without interfering with its vibration.

Observations and Calculations.

The method of making the observations in the case of springs 1, 2 and 6 was as follows:—The relation between the length and tension was determined, the tension being first increased from zero until the increase in length was no longer propor-

tional to the increase in tension, and then being decreased to zero again. Immediately after this the relation between the length and frequency was determined, starting with as short a length as possible and increasing it up to the maximum length obtained above and then decreasing it again as far as possible. The relation between the length and tension was then again obtained as in the first place. A complete set of observations for spring 1 is given in Table II.

Table II.

T.	Out L.	In L.	L.	Out n.	In n.	T.	Out L.	In L.
0	9·32	9·33	10	14·80	14·69	0	9·34	9·34
10	10·02	10·08	11	18·16	18·01	10	10·07	10·10
20	11·40	11·48	12	20·43	20·31	20	11·46	11·49
30	12·81	12·90	13	22·13	22·04	30	12·88	12·94
40	14·23	14·32	14	23·45	23·41	40	14·28	14·35
50	15·68	15·76	15	24·62	24·50	50	15·73	15·80
60	17·13	17·18	16	25·49	25·47	60	17·16	17·21
70	18·60		17	26·26	26·22	70	18·64	
			18	26·93				

Here T is the tension measured in grams, L is the length measured in cm., and n is the number of vibration per second. "Out" means increasing, and "In" decreasing tension or length.

The first set of values between length and tension was preliminary, taken to find the point at which the relation between the length and tension ceased to be linear. This stretching of the spring also served to remove certain very slight irregularities, as was evident when several length-tension sets were taken in succession, in which case the behavior of the spring was practically the same in all sets except the first. Therefore in making the plots and calculations the mean of the length-frequency and final length-tension sets were used, and in general only these values have been recorded in the tables.

Table III gives the mean values of L and n from Table II, also the calculated values of n and the difference between the observed and calculated values.

Table III. (Spring 1.)

T.	L.	L.	Observed n.	Calculated n.	Difference.
0	9·34	10	14·74	15·08	— 0·34
10	10·09	11	18·08	18·16	— 0·08
20	11·47	12	20·37	20·37	0·00
30	12·91	13	22·08	22·06	+ 0·02
40	14·32	14	23·43	23·41	+ 0.02
50	15·76	15	24·56	24·52	+ 0·04
60	17·19	16	25·48	25·45	+ 0·03
70	16·64	17	26·24	26·24	0·00
		18	26·93	26·92	+ 0·01

Figure 4 gives the length-tension and length-frequency curves plotted from the values given in Table III. The full and dotted lines represent respectively the observed and calculated curves; the observed points are surrounded by circles, and the calculated points are indicated by crosses. In case the observed and calculated curves agree too closely to show both, the calculated curve will be given, and the observed points indicated by circles.

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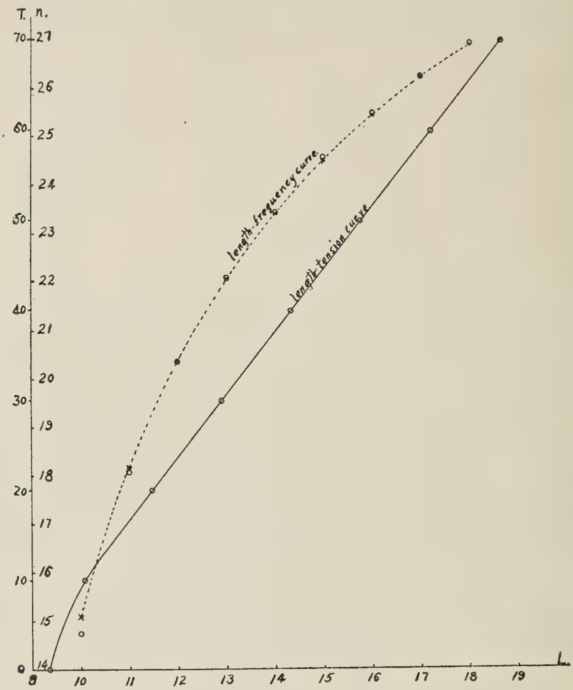

It is evident from the plot that the relation between the length and tension is practically linear through nearly the entire range used. This relation is most simply expressed by the equation

$$\text{(1)} \qquad T = mL + x$$

where m is the slope of the line, and x is the point at which, if continued, it would intersect the T axis.

In order to find the relation between length and frequency, it seemed most natural to take the usual expression for a vibrating string, which for the present purpose is most conveniently written in the form

(2) $$n = \tfrac{1}{2}\sqrt{\frac{T}{L}\,\frac{g}{M}}$$

where M is the total mass of the spring. If T is now eliminated between (1) and (2) the relation between L and n takes the form

(3) $$n = \tfrac{1}{2}\sqrt{\frac{mL + x}{L}\,\frac{g}{M}}.$$

The values of n calculated by this formula differed considerably from the observed values, as might have been expected, for in the first place the values used for T entirely ignored the weight of the spring and were therefore always too small, and in the second place the length of the spring was taken as the distance between the two blocks A and B (fig. 1), which was evidently somewhat greater than the true vibrating length. In order to avoid these two difficulties, another constant was added to equation (3). Two equations similar to (3), but with this added constant, were then used to solve for the unknown quantities x^1 and y.

(4) $$\begin{cases} n_1 = \tfrac{1}{2}\sqrt{\dfrac{mL_1 + x^1}{L_1 + y}\,\dfrac{g}{M}} \\[2ex] n_2 = \tfrac{1}{2}\sqrt{\dfrac{mL_2 + x^1}{L_2 + y}\,\dfrac{g}{M}}. \end{cases}$$

Solving for y and x^1 gives

(5) $$y = \frac{N_1 - N_2 + K_2 - K_1}{4n_1^2 - 4n_2^2}$$

(6) $$x^1 = \frac{M}{g}\,(K_1 + 4n_1^2 y - N_1)$$

where $N_1 = \frac{mg}{M}L_1$; $N_2 = \frac{mg}{M}L_2$; $K_1 = 4n_1^2 L_1$; $K_2 = 4n_2^2 L_2$.

The value of m is always taken as the slope of the straight part of the length-tension curve; L_1, n_1, L_2 and n_2 are corresponding values of L and n taken from the length-frequency curve. The values of the constants for spring 1 are as follows:

$M = 1{\cdot}2834$	$m = 7{\cdot}00$
$L_1 = 12$	$n_1 = 20{\cdot}37$
$L_2 = 17$	$n_2 = 26{\cdot}24$

Substituting these values in (5) and (6) gives

$$y = -\ 0{\cdot}1714$$
$$x^1 = -58{\cdot}29$$

and putting these values in (4) gives the equation in its final form

$$(7) \qquad n = \tfrac{1}{2}\sqrt{\frac{L-8{\cdot}328}{L-0{\cdot}1714} \cdot \frac{7{\cdot}00 \times 980}{1{\cdot}2834}}$$

The values of n calculated by this formula are given in Table III and are plotted in fig. 4.

The results obtained with springs 2 and 6 were so similar to those obtained with 1 that it is unnecessary to give them here.

In order to study the behavior of a spring beyond the point where the length and tension were linearly related, it was necessary to modify the method of making the observations. The series with decreasing lengths was in all cases omitted, and several hours were left between successive sets of observations, so that the spring might recover as far as possible its original condition. Table IV and fig. 5 give the results for spring 3 obtained in this way.

Table IV. (Spring 3.)

T.	L.	L.	Observed n.	Calculated n.	Differences.
0	7·74	8	12·45	13·05	−0·60
10	8·62	9	16·89	17·09	−0·20
20	9·51	10	19·71	19·71	−0·00
30	10·41	11	21·62	21·61	+0·01
40	11·30	12	23·05	23·06	−0·01
50	12·20	13	24·21	24·22	−0·01
60	13·10	14	25·15	25·16	−0·01
70	14·00	15	25·96	25·95	+0·01
80	14·91	16	26·62	26·62	−0·00
90	15.84	17	27·16	27·19	−0·03
100	16·75	18	27·64	27·69	−0·05
110	17·69	19	28·07	28·13	−0·06
120	18·62	20	28·41	28·52	−0·11
130	19·59	21	28·73	28·87	−0·14
140	20·50	22	28·98	29·18	−0·20
150	21·45	23	39·19	29·46	−0·27
		24	29·30	29·71	−0·41

Data used in the calculations for spring 3:

$M = 2{\cdot}210 \qquad m = 11{\cdot}04$

$L_1 = 10 \qquad n_1 = 19{\cdot}71$

$L_2 = 16 \qquad n_2 = 26{\cdot}62$

$y = -0{\cdot}333 \qquad x^1 = -76{\cdot}55$

In fig. 5 it is seen that the difference between the observed and calculated values of n becomes greater the further the length-tension curve departs from a straight line. This is just what would be expected, if springs obey the same law as vibra-

ting strings, in fact the equation requires that the percentage difference between the observed and calculated values of the frequency for a given length shall be twice the percentage difference between the observed and calculated values of the tension for the same length. If careful measurements are made on the plot, this will be found to be approximately true.

It is also seen in fig. 5 that n is apparently approaching a maximum value. This fact made it seem desirable to carry the curves considerably further beyond the point where the length and tension are linearly related. Since for this case only a

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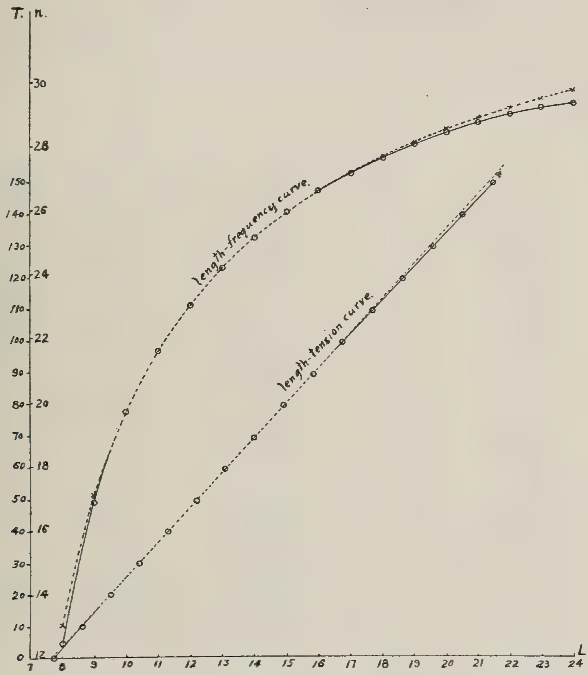

single set of observations could be made with one spring, on account of the permanent distortion produced, the most practicable method seemed to be to make two springs as nearly alike as possible. This was accomplished quite satisfactorily by cutting into two parts a very uniform spring and then adjusting the two parts until they had as nearly as possible the same mass, length and rate of extension.

Springs 4 and 5 were treated in this way, but the results were so similar that only those for 4 will be given. Table V shows how similar were the two parts into which spring 4 was made.

TABLE V.

T.	4a L.	4b.
0	12·18	12·18
20	13·63	13·63
40	15·10	15·08
60	16·56	16·55
80	18·03	18·03
100	19·53	19·51

Mass of $4a = 3·769$
" $4b = 3·783$

Springs $4a$ and $4b$ are certainly similar enough for the purposes of this investigation. The relation between the length and tension was determined with $4b$ and the relation between the length and frequency with $4a$. Table VI and fig. 6 give these results.

TABLE VI.

Spring 4b		Spring 4a			
T.	L.	L.	Observed n.	Calculated n.	Difference.
0	12·18	13	9·82	10·21	−0·39
20	13·63	14	12·56	12·72	−0·16
40	15·08	15	14·45	14·55	−1·10
60	16·55	16	15·92	15·96	−0·04
80	18·03	17	17·11	17·11	0·00
100	19·51	18	18·09	18·07	+0·02
120	21·00	19	18·91	18·88	+0·03
140	22·50	20	19·61	19·58	+0·03
160	24·00	22	20·75	20·72	+0·03
180	25·51	24	21·63	21·63	0·00
200	27·05	26	22·31	22·36	−0·05
220	28·66	28	22·85	22·98	−0·13
240	30·23	30	23·26	23·48	−0·22
260	32·03	32	23·58	23·92	−0·34
280	33·90	34	23·81	24·30	−0·49
300	35·90	36	23·88	24·63	−0·75
320	38·38	38	24·02	24·92	−0·90
340	40·83	40	24·02	25·18	−1·16
360	43·80	42	24·01	25·42	−1·41
380	46·60	44	23·88	25·63	−1·75
400	50·00	46	23·76	25·81	−2·05
		48	23·60	25·99	−2·39
		50	23·44	26·14	−2·70

Data used in the calculations for spring $4a$:

$M = 3·769$	$m = 13·50$
$L_1 = 17$	$n_1 = 17·11$
$L_2 = 24$	$n_2 = 21·63$
$y = -0·596$	$x^1 = -155·6$

The length-frequency curve for spring $4a$ differs from the others thus far studied in that the frequency has passed beyond the maximum point. If the frequency of the vibrations of the springs, when stretched beyond the elastic limit, obeys the same law as before, then along the flat maximum of the curve where

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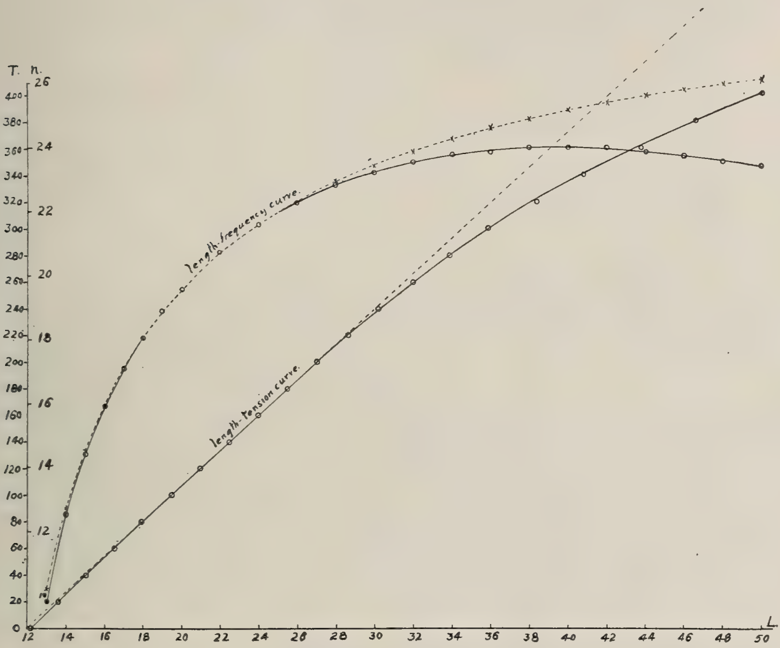

n is nearly constant, the ratio of T to L ought also to be nearly constant. An examination of fig. 6 gives the following values for n and $\frac{T}{L}$ for a few values of L along this part of the curve.

TABLE VII.

From Fig. 6.

L.	n.	$\frac{T}{L}$
34	23·81	8·26
36	23·88	8·36
38	24·02	8·34
40	24·02	8·32
42	24·01	8·29
44	23·88	8·22

The above table makes it seem very probable that the frequency of vibration of a spring would be approximately constant through a long range of lengths, if it could be so made that $\frac{T}{L}$ would be constant along the linear part of the length-tension curve, or in other words if x in the equation $T = mL + x$ could be made zero. Spring 7 was made with this end in view. It differed from all the other springs made by having its turns

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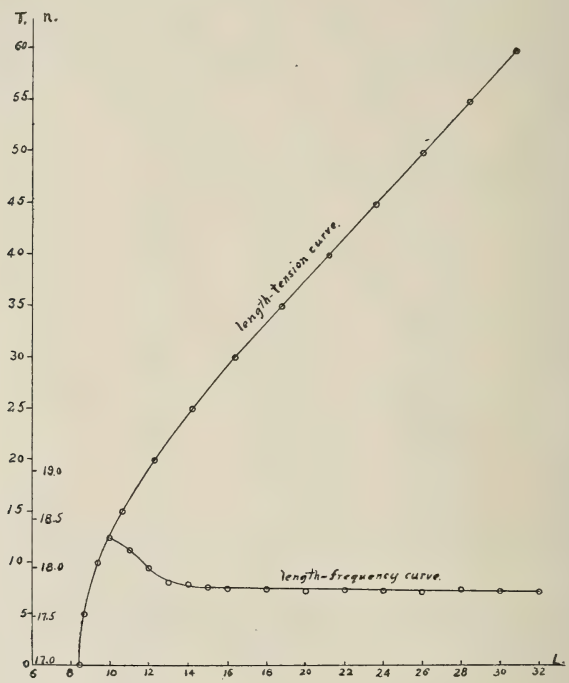

wound so tightly together that they did not become entirely separated until loaded with about 30 grams. The winding of this spring was more difficult than that of the others, and it was not nearly so uniform, but its frequency was very constant, differing only by one-twentieth of a vibration per second when its length was increased from 15 cm. to 32 cm.

The results for spring 7 are given in Table VIII, and the values are plotted in fig. 7.

TABLE VIII. (Spring 7.)

T.	L.	$\frac{T+x}{L}$	L.	n.
0	8·43		10	9·32
5	8·69		11	9·18
10	9·37		12	9·01
15	10·63		13	8·86
20	12·31		14	8·84
25	14·22	1·990	15	8·81
30	16·42	2·028	16	8·79
35	18·80	2·037	18	8·78
40	21·23	2·040	20	8·77
45	23·66	2·041	22	8·78
50	26·09	2·043	24	8·77
55	28·51	2·045	26	8·76
60	30·90	2·048	28	8·78
			30	8·76
			32	8·76

In calculating the ratio of T to L, a small correction x equal to about one half the weight of the spring was added to T. As was expected, the frequency was very constant through the same range that $\frac{T+x}{L}$ was constant.

Sufficient evidence, I think, has been furnished to show that vibrating helical springs obey the same law as vibrating strings through a considerable range of length and tension. It would seem of interest now to examine the behavior of india-rubber cords under conditions as similar as possible to those experienced by the springs and to compare their behavior. For this pur-

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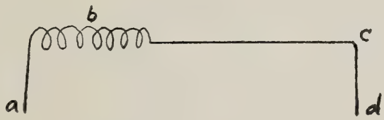

pose two samples of as pure rubber as could be obtained were used; one a rubber tube of about 4·68 mm. external and 3·06 mm. internal diameter, the other a rubber cord of square cross section, 1·16 mm. on a side.

The observations were taken in the same way as in the case of the springs, except that a slight modification had to be made in order to get electrical connection. In the case of the rubber tube a U-shaped piece of wire was hung on its center and held fast with rubber cement. The vibrations of the tube caused the two ends of the wire to dip into two mercury cups. In the

case of the rubber cord the contact was made by a very fine wire bent as shown in fig. 8.

The end *a* was firmly fastened. The point *c* was fastened with rubber cement to the rubber cord, the vibration of which caused the point *d* to dip into a mercury cup. The spring *b* was used to increase the flexibility of the wire until it had practically no period of vibration of its own. While there are some objections to this method of making the contact, the weight of the wire was so small and the adjustments made with such care, that the results are sufficiently satisfactory for com-

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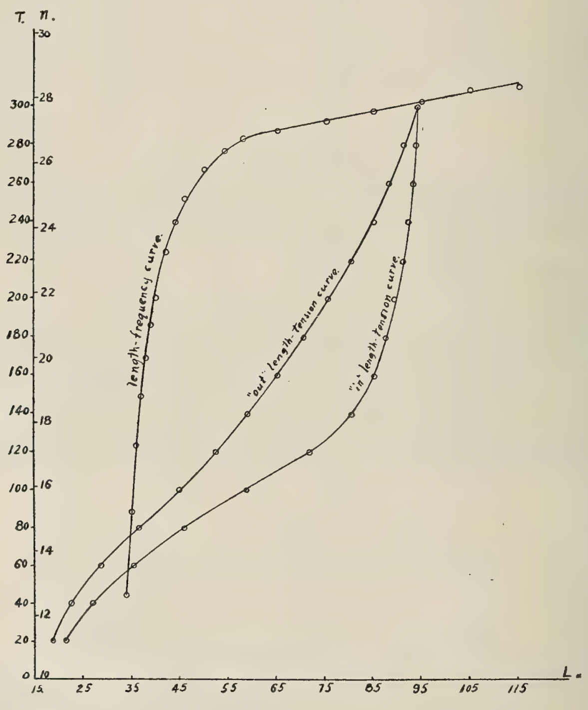

parison with those of the springs. In all cases with the rubber the successive observations were made as rapidly as possible, in order that time effects might be reduced to a minimum. Between the length-frequency observations and the length-tension observations time was allowed to elapse until the rubber practically recovered its original length.

The tube and the cord gave very similar results; those for the cord are given in Table IX and fig. 9.

TABLE IX. (Rubber cord.)

L.	n.	T.	Out L.	In L.
34	12·60	0	16·20	17·6
35	15·18	20	18·74	21·3
36	17·25	40	22·62	27·0
37	18·78	60	28·7	35·4
38	19·95	80	36·6	46.0
39	20·98	100	44·9	58·8
40	21·83	120	52·4	71·8
42	23·23	140	59·0	80·4
44	24·15	160	65·2	85·1
46	24·88	180	70·5	87·4
50	25·80	200	75·6	89·1
54	26·35	220	80·3	90·9
58	26·73	240	84·9	92·0
65	27·00	260	88·0	92·9
75	27·28	280	91·0	93·6
85	27·60	300	93·8	
95	27·90			
105	28·25			
115	28·38			

The similarity of the curves obtained with the rubber cord and those obtained with the springs is very noticeable. This is especially true for the first part of the length-tension curves in figs. 7 and 9, which would seem to indicate that the rubber is in a state of internal stress, even when there is no external tension, which was certainly true in the case of spring 7. Fig. 9 also shows what a very important effect the previous condition of the rubber has upon the relation between the length and tension. The condition of the rubber is also to a considerable degree dependent upon time and temperature, which explains why it is so difficult to make satisfactory measurements with it.

Although there are some irregularities in the curves given, especially those for the rubber, and for the springs when the tension was so small that the effect of the restraint of the ends was considerable, yet the following conclusions seem to be justified:

1. In the study of the transverse vibrations of helical springs and india-rubber cords one radical difference is noticed between them and ordinary strings, namely the fact that their length varies greatly with the tension instead of remaining very approximately constant.

2. While the frequency of the vibrations of the springs and rubber cord is expressed by the formula usually employed in the case of ordinary strings, yet the results obtained are very different on account of the great variations of the length with the tension.

3. The approximate constancy in pitch for a considerable change in length, which has been so often noticed with india-rubber cords, is also observed in a still more marked degree in the case of helical springs.

4. This approximate constancy of pitch for a considerable change in the length of both the rubber cords and the springs is due to the fact that during the change, the length and tension have remained nearly proportional.

In conclusion I desire to express my thanks to Professor A. W. Wright for suggesting the subject and furnishing the apparatus and assistance necessary in carrying on the investigation. I wish also to thank Mr. O. C. Lester for his assistance in performing the experimental work.

Sloane Physical Laboratory,
Yale University, May 1, 1904.

Art. XI.—*A new Type of Calcite from the Joplin Mining District;* by Douglas B. Sterrett.

During the past spring an interesting type of calcite crystals has been added to those already produced by the prolific Joplin region. The crystals are all twins and show a uniformity of a development unusual for the species. They were obtained from a small cave discovered in the Maybell Mine at North Empire, Kansas. According to Mr. W. L. Bachtell, who has had charge of the removal of the crystals, the cave was opened at a depth of 135 feet while blasting in the chert. It was 50 feet long, 4 to 8 feet high and 6 to 12 feet wide. Specimens were sent by Mr. Bachtell to Prof. E. S. Dana at New Haven, and it is at his suggestion that this brief study of their forms and development has been undertaken. These specimens, with others loaned to the writer by Mr. George L. English of New York, and one from the Brush collection, were used in the preparation of this article. Mr. English described this new occurrence in a lecture before the New York Mineralogical club on March 15th. Since his lecture was not published, it has been deemed advisable to give a brief description of the occurrence and of some characteristic specimens.

Most of the crystals are very large. Mr. English states that according to the information that has come to him, probably less than two hundred were obtained from the cave, and only some dozen or so were of a size suitable for cabinet drawer specimens. One of the larger crystals, now in the Yale College collection, measures $39{\cdot}5^{cm}$ along the reëntrant angle, 19^{cm} in thickness and 30^{cm} high, according to the orientation chosen in fig. 1. This crystal weighs 62 pounds and is very well developed for one of such size. Probably the smallest is the one shown in fig. 2, which is only $4{\cdot}7^{cm}$ in greatest length. One remarkable feature which most of these crystals possess is a delicate amethystine or lilac color, much resembling that of the pale-colored kunzite. The color is not uniformly distributed through the crystals, but is confined chiefly to the outer parts and appears to lie in a plane parallel to the crystal faces, especially the *e* face. Owing to their form and great beauty of color, they are called the "amethystine twin calcites."

The crystals are twinned on the *e* face ($01\bar{1}2$), according to a very common law for calcite. In representing them, drawings were made with the twinning plane vertical (as in figs 1 and 2), also with the lower crystal in normal position for a positive form while the upper negative crystal was tilted back into twin position (as in figs. 3, 4 and 5). Measurements were made

on some of the smaller crystals, the quality of which allowed very satisfactory determinations of the following forms:

r $(10\bar{1}1)$	f $(20\bar{2}1)$	t $(21\bar{3}4)$
M $(40\bar{4}1)$	l $(40\bar{4}5)$	C $(61\bar{7}8)$
m $(10\bar{1}0)$	e $(10\bar{1}2)$	

The l face on most of the crystals is so etched as to be difficult to measure. On one small crystal, however, it gave fairly good reflections and an average value was obtained of $m \wedge l = 51° 56'$; theory $51° 43'$. The C faces appeared to be only vicinal growths on r, but when measured gave good reflections and an average value of $C \wedge r = 8° 44\frac{1}{2}'$; theory $8° 46'$.

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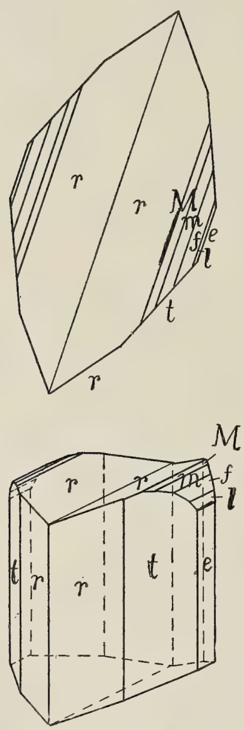

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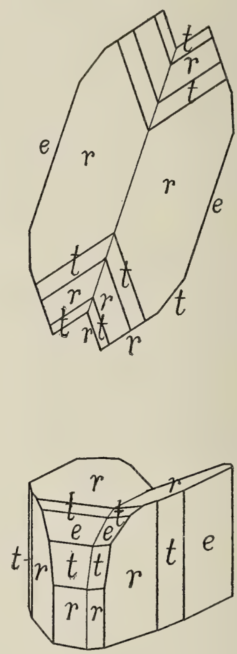

Fig. 1 represents a quite symmetrically developed crystal belonging to the Yale College collection. It was found that a drawing, made in clinographic projection with the twinning plane vertical, gave little idea as to the length along the twinning plane; so orthographic projections were also made to accompany figs. 1 and 2. Fig. 2 shows the development of

a small crystal loaned by Mr. English. It might be considered as made up of two separate individuals grown together in twin position. On each the zone *r*, *t* and *e* appears three times. There was a very small development of the faces of the zone *r*, *M*, *m* – – – and *e* in their proper positions, though these are not shown in the figure. Fig. 3 represents an ideal

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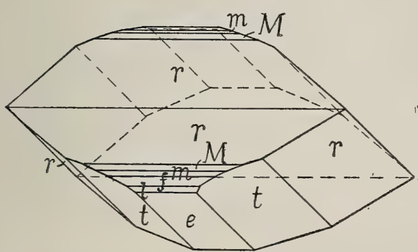

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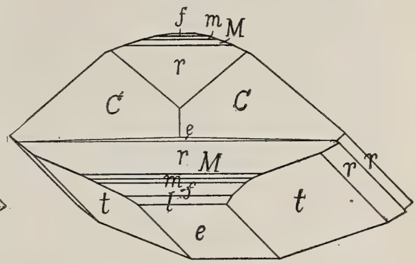

development of a crystal which is given in its natural distortion in fig. 4. The *C* faces were not drawn in fig. 3, since they occur only on one of the twins. As shown in fig. 4, they form an intersection with the twinning plane *e*, which extends above the line of intersection of the twin crystals. This crystal is apparently terminated below by natural *r* faces parallel to those above and forming an obtuse angle. In most of the crystals a natural termination fails, and its place is occupied by cleavage planes developed when the crystals were detached from the rock. On some crystals the *e* face is wanting, in

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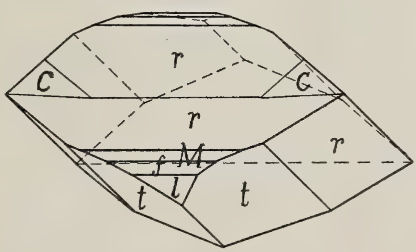

which case *l* has a larger development, as shown in fig. 5. This represents a large specimen in the Brush collection on which the *C* faces appear again only on one of the crystals. In this case they form no intersection with the twinning plane, as in fig. 4, but together with *r* of the upper crystal overlap the lower one, meeting the *r* of the latter beyond the twinning

plane. The occurrence of C on only one individual of a twin was observed on four specimens, while on the large crystal described above, C occurred on both.

The crystals show a tendency toward a prismatic development parallel to the *e* faces. This was further marked by pits or negative crystals of prismatic form observed on the *e* faces of one crystal. The faces of the negative crystal were parallel to the unit rhombohedrons, and therefore rhombohedral themselves. One crystal, probably from another opening in the same mine, showed the same method of twinning, though this fact was nearly concealed by the development of very large *v* faces nearly covering the reëntrant angle of the twins.

The development of a twin crystal similar to those described above was observed on a single specimen of golden calcite from the Joplin region about two years ago by Mr. English.

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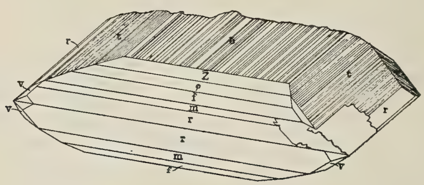

At his request, a drawing of it was prepared by Mr. H. P. Whitlock; Mr. English has kindly allowed a copy of the figure to be inserted here for comparison. The letters represent forms found in Dana's System of Mineralogy. Whether other crystals were found and what was the exact locality for this could not be learned.

In conclusion, acknowledgment is made to Mr. English for generously supplying material for examination, and to Prof. E. S. Dana and Dr. W. E. Ford for assistance in the preparation of this paper.

Sheffield Laboratory of Mineralogy,
Yale University, New Haven.

ART. XII.—*Radium and the Electron Theory;* by JOHN TROWBRIDGE and WILLIAM ROLLINS.

THE mechanism of electric conduction through metals continues to be one of the greatest mysteries of electricity; and there is no plausible explanation of it unless we accept the theory of electrons. This theory, as is well known, supposes the existence of small bodies called electrons, which move between the molecules of the metals during the passage of an electric current. It has been much developed by Drude.*

The theory seems to bring the electrical conduction in metals into close touch with conduction in gases; for in both cases we suppose a movement of small particles. These particles have a greater free-path in rarified gases than they have between the molecules of a metal, and their action is much modified by the X-rays. This modification is usually attributed to a species of ionization due to a physical connection between the energy emitted by the X-rays and the transformation of energy witnessed in the rarified gas. A Geissler tube, for instance, which will not permit the passage of an electric current, when the degree of exhaustion is beyond the point of breaking down with the electromotive force employed, is made conducting when the X-rays fall upon it.

We mention this fact in order to give a significance to our experiments with radium. This remarkable substance, also, in common with the X-rays can affect by what we call ionization, the conduction of electricity through gases. The X-rays and certain emanations of radium can also pass through thin sheets of metal, especially sheets of aluminium. We are, therefore, for the first time in the history of electricity, in a condition to test the question, whether radiant energy exhibiting light and passing through a metal can affect the passage of a current of electricity.

In this connection one is immediately reminded of Faraday's attempt to discover whether ordinary light is modified in passing through an electrolyte which is submitted to the action of a current of electricity. He thought that there might be a state of tension which could be detected by polarized light; and he therefore passed a beam of polarized light in the direction of the current and also at right angles to this direction. The result of the experiment was negative; absolutely no effect was observed. Faraday's custom of publishing both positive and negative results has its advantages, especially in the early days of a science; and particularly when it shows us

* Ann. der Physik., No. 1, 1900.

the working of a great mind groping in a region not yet submitted to calculation. Lesser minds must, however, use caution in publishing negative results; for due regard must be had for brevity of publication and the limits of experimentation.

Can we not, however, imagine Faraday continuing his efforts to discover some connection between the passage of light through an electrolyte or a conductor and the passage of a current of electricity, if he could penetrate such a conductor by light. In other words, might he not have been tempted, if he had had command of the X-rays or radium, to discover some action of the energy emitted by the new and wonderful manifestations on a current? Apart, however, from such a view of the working of the great physicist's mind, can we not get a foothold in mounting to the heights of the electron theory by endeavoring to show that the X-rays or the emanations from radium do or do not have a discoverable action upon the passage of an electric current, through aluminium for instance?

It must be premised that no mass is ascribed to the electron. Its supposable inertia is due to self-induction, and perhaps it should not be called a body. On this conception it does not seem probable that particles shot off from radium, or ions resulting from the radiation of X-rays, could influence such immaterial bodies. Nevertheless our view of the electron theory might be influenced by proceeding to an actual test, and by looking at the results and limitations of possible experiments. We therefore experimented as follows:

A meter of aluminium wire No. 24 was wound in five turns around a thick sheet of lead which was eight centimeters in length and one centimeter in width. The wire was wound around the longest dimension of this shuttle-like piece of metal, and was insulated from it by thin sheets of vulcanite. The electric current, therefore, passed in one direction along the upper layer of the wire, and in the opposite direction along the lower layer. The lead, intervening between the upper and lower layer, could serve to confine the radiations from suitably placed radium either to the upper or the lower layer of wire. The lead shuttle with its layer of wire was enclosed in a lead cylinder and a specimen of pure radium bromide was enclosed at one end of the layers of wire so that its emanations could sweep along the upper or the lower layer of this wire. A lead diaphragm could be used to shut off the entire effects of the radium from the wires.

The wire was made one branch of a Carey-Foster bridge; a suitable key made it possible to reverse the current through the aluminium wire, and after adjustment the wire was exposed to the radiations from the aluminium under the varying conditions of reversals of current; radiations confined to the lower layer

and afterwards to the upper layer. The bridge was competent to detect a change in resistance of one hundredth-thousandth of an ohm. On account of the difficulty of distinguishing between a heating effect and what may be called an electrodynamic effect, the observations occupied a comparatively short interval of time. No instantaneous effect was observed: a very slight creeping deviation of the galvanometer mirror came after a considerable interval of time, which might have been due to change of temperature. It could not be ascribed with reason to the presence of the radium.

The light from the radium could be seen through a slab of iron an inch thick; yet this manifestation of energy passed through the aluminium without any apparent effect upon the mechanism of the electric current. Should we reason, therefore, from this negative experiment that the theory of the immaterial electron is supported, or that a theory of dissociative effect on gases between each molecule of the metallic conductor under the effect of a current is also negatived: for the radium emanations, like the X-rays, can produce this dissociative effect in the passage of electricity through gases?

Mr. McKay, graduate student working in this laboratory, has endeavored to detect the effect of the X-rays in changing the apparent resistance of thin films of metals. The effect, if it exists, is extremely small. He, however, is still continuing his work upon this subject.

Jefferson Physical Laboratory,
Harvard University.

ART. XIII.—*Pseudomorphs and Crystal Cavities;* by J. P. ROWE.

SOME of the finest pseudomorphs and crystal cavities the writer has ever seen came to his notice recently from specimens collected near Shoshone, Idaho. The material was collected and sent to the University of Montana by Rev. T. L. Lewis. The natural mineral is pyrite, imbedded crystals; the pseudomorph, limonite; and the matrix, a fairly pure, light colored, quartzite.

Specimens were found showing the unaltered pyrite cubes below imbedded in pure homogeneous quartzite, the pseudomorphs of limonite above in the same material, and still higher the beautiful and perfect cavities, where the pseudomorphs had been dissolved out by the action, probably, of meteoric water. Almost all of these cavities show the delicate striations of the pyrite cubes. The matrix is literally filled with these cavities and presents a regular honeycombed appearance. The size of the cavities range from ·15 of a centimeter in diameter to 2·5 centimeters. However, but few if any of the cavities are perfect cubes. One of the most interesting things about these specimens is, that the distance from the pyrite crystals to the crystal cavities, i. e. including the pseudomorph limonite, in many instances, is not more than five centimeters. In fact, in many cases the pseudomorphs are not more than 1·5 to 2 centimeters from the pyrite crystals.

Taking it all in all the specimens are very beautiful. They show the transition of the pyrite to the limonite as do but very few specimens. They also show that limonite is easily soluble in certain kinds of water. They still show how these cavities might be refilled with quartz or calcite or some other mineral from solution and again give false forms, not true pseudomorphs as in the first instance, but so to all appearances.

University of Montana, Missoula, April 29, 1904.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *Emanium.*—F. Giesel has obtained from pitchblende an earth consisting chiefly of lanthanum which shows strong radioactive properties. He finds that the behavior of the material is different from that of radium, and believes that he has obtained a new element which he calls emanium and which he hopes to separate from lanthanum. The striking characteristic of this material appears to be an emanation given off by it. When air is blown through a flask containing preparations of the substance enclosed in paper capsules, and the air issues from a tube against a blende screen, a brilliant illumination is produced, and scintillations can be observed, even with the naked eye. The "sparks" are more distinct and larger than those produced by radium or polonium, and hence the material is more effective than these for use in the spinthariscope.—*Berichte*, xxxvii, 1696. H. L. W.

2. *Radio-activity and Matter.*—This topic has been recently discussed by Professor Winkler, who is perhaps the most prominent inorganic chemist in Germany. The great importance of the recent discoveries connected with radio-active substances is admitted, but the author doubts that the existence of new elements in this connection has been satisfactorily demonstrated. He is inclined to consider radio-activity as a purely physical process, which, like magnetism, may act upon matter without affecting its chemical nature. He points out that radium, which was discovered nearly six years ago, is but slightly known in its chemical relations, and that nothing can be stated about it in this respect, except that it is remarkably similar to barium, but has a higher atomic weight. The further chemical study of radium and other radio-active substances is advocated, and the suggestion is made that material for such work may be obtained from certain rocks, especially granites, occurring in Germany, which are known to contain uranium minerals.—*Berichte*, xxxvii, 1655.
H. L. W.

3. *Detection of Chlorides in the Presence of Bromides.*—Many methods have been proposed for the detection of small quantities of chlorides in the presence of bromides in qualitative analysis, but most of them present difficulties in the hands of students. Chapman Jones has recently proposed for this purpose the treatment of the mixed silver salts with a cold saturated solution of ammonium bicarbonate. The reagent is poured over the precipitate on the filter paper and is acidified with nitric acid after it has run through. When the reagent is allowed to remain in contact with silver salts for a few minutes with occasional agitation, the precipitate produced by acidifying will be greater in the case of the chloride, while the treatment of the bromide may be continued sometimes for half an hour without giving a positive result. In a case of doubt, the acidified liquid may be

divided into two parts; to one is added a slight excess of ammonium bicarbonate solution, and to the other an equal quantity of water. If the turbidity is due to silver chloride, it will dissolve in a few moments, but if it is due to the bromide it will remain undissolved for several minutes, if not for an hour or more.—*Chem. News*, lxxxix, 129. H. L. W.

4. *Solubility of Silicon in Zinc and Lead.*—MOISSAN and SIEMENS have found that silicon dissolves in zinc at a much lower temperature than in lead. In zinc the solubility begins at 550°, and amounts to 1·6 per cent at 850°. In the case of lead the solubility begins at 1100°, and at 1400° it amounts to only 0·15 per cent, while at the boiling-point of lead, about 1550°, it amounts to only about 0·79 per cent.—*Berichte*, xxxvii, 2086. H. L. W.

5. *Analytical Chemistry, Volume II, Quantitative Analysis;* by F. P. TREADWELL: translated from the Second German Edition by William F. Hall. 8vo, pp. 654, with 96 figures. New York, 1904. (John Wiley & Sons, price $4.00.)—A satisfactory text-book for students in quantitative analysis has long been needed, and it appears that the work under consideration will fill this want admirably, and that it will be a most useful book of reference for practical analysts. The most modern and satisfactory methods of analysis are ably presented, and the book is not encumbered with antiquated and superseded processes. The best electrolytic methods are included, as well as methods of fire assaying for gold and silver ores, while separate parts of the book give excellent treatises on volumetric analysis and gas analysis. The modern aspect of the work will be evident when it is stated that the use of the Gooch crucible is strongly advocated (although the details given for its use appear to be unduly complicated, probably from lack of experience with the proper kind of asbestos), and also from the fact that many other American methods, such as those of Gooch and his pupils, Hillebrand, and others, are given. This attitude towards American improvements is in agreeable contrast with the usual conservatism displayed in this respect by European works on analytical chemistry. The translator has also helped in this direction by making certain additions and changes with the object of rendering the book more useful to English-speaking students. H. L. W.

6. *Laboratory Exercises in Physical Chemistry;* by F. H. GETMAN. 12mo, pp. 241. New York, 1904. (Wiley & Sons.)—There has been previously no suitable laboratory text-book in physico-chemical measurements which could be used by the average student, and the present volume has been written to meet this requirement. The customary measurements in physical chemistry are well described in detail, with the apparatus required. Usually but one method is given for each measurement. We notice that in describing the boiling-point apparatus only the Jones form is described, while no mention is made of the Beckmann form. There is a set of convenient tables added at the end of the book. H. W. F.

7. *Chemie der Eiweisskoerper;* von Dr. OTTO COHNHEIM; Zweite Auflage, Braunschweig, 1904. (Fr. Vieweg und Sohn.)—The publication, in 1900, of a monograph of three hundred pages devoted to the literature of the chemistry of the proteids emphasized the importance which the study of this unique and significant group of compounds has assumed in biological chemistry. The appearance, scarcely four years later, of a new edition of Cohnheim's book, not merely revised but entirely rewritten, gives evidence of the marked progress which has attended recent investigation in this field of study. It is no exaggeration to say that during this interval our ideas regarding the structure of the albuminous bodies have been radically altered in various ways. Investigators and students will therefore welcome the new edition as a useful aid. The judgment which the author has displayed in dismissing with brief reference those theories and facts which no longer possess more than historical interest, and in directing attention to the permanent acquisitions to our knowledge, deserves commendation. From this it will be understood that Cohnheim's book is something more than a mere compilation; indeed, critique is displayed in every chapter. The more important advances appear in the review of the cleavage products of the proteids and in a discussion of their chemical constitution. The almost unavoidable occasional omissions of reference to important papers are apparently few; and the completeness thus attained gives an added value to the work. L. B. M.

8. *Vapor pressure of Mercury at ordinary Temperatures.*—EDWARD W. MORLEY gives a résumé of the work of previous observers of this pressure. The work of Regnault must be dismissed from consideration, for his experimental means were not sufficiently delicate and precise. Hagen's measurement also must be disregarded because his interpolation formula is inconsistent with what we know of the behaviour of saturated vapors. The experiments of Hertz, of Ramsay and Young, agree with those obtained by Morley, while those obtained by Van der Plaats differ widely. A table of vapor pressures is appended to the article.—*Phil. Mag.*, June, 1904, pp. 662–667. J. T.

9. *The Penetrating Rays of Radium.*—The γ-rays of radium have been likened to the X-rays on account of their penetrating power and their not being deflected by a magnet. E. PASCHEN has made a study of this penetrating power. The rays have a very different absorption-coefficient from the X-rays. The author points out incidentally, that the commonly based method of ionizing the air is not suitable for determining the absorption. The rays lose their power of ionizing the air in passing through layers of lead. The γ-rays appear to have a velocity approximating to that of light and they possess great interest; for we apparently have in their case electrical quantities moving with the velocity of light.—*Ann. der Phys.*, No. 6, 1904, pp. 164–179. J. T.

10. *Use of the Thread Galvanometer.*—W. Einthoven described in Ann. der Phys., p. 1059, 1903, a galvanometer which consisted in the main of a silvered quartz fiber stretched between the poles of a magnet. He now explains some further peculiarities and uses of the instrument. He has repeated the Curies' measurement of radio-activity of various substances by the use of his instrument instead of the electrometer and finds it more suitable for the purpose. The currents measured were of the order 5×10^{-11} amp. He also measured insulation resistances of the order of a million megohms. A quantity of electricity 5×10^{-12} ampere-seconds can be detected. In general the instrument is suitable for many uses to which the electrometer has been put; and it is especially useful to detect and measure feeble sounds or telephone currents.—*Ann. der Phys.*, No. 6, pp. 182–192, 1904. J. T.

11. *The Hot Oxide Coherer.*—Max Hornemann states that he described this coherer in 1902, while Branly's paper on the same subject appeared in 1904. Heated and then cooled particles of iron possess, on account of the layer of oxide, a peculiar sensitiveness to electrical waves. The author had shown this property of cold oxide layers and lately has investigated the influence of heat on the sensitiveness of such layers. He found that hot layers of the oxide, if they are of the same metal throughout, do not possess any marked superiority over the cold particles; but if he used layers of different metals, for instance, lead with an oxidized (not noble) metal, he obtained a much greater sensitiveness. With a hot lead copper contact he could detect the purring of a little induction coil at a distance of 12 meters and through intervening walls.

Hornemann has studied this effect of the heated oxide layer by means of a galvanometer and suitable electric circuits; but is not certain of the reason for this peculiar action of heat on the coherer. The property seems to be an important one with reference to wireless telegraphy.—*Ann der Phys.*, No. 6, pp. 129–138, 1904. J. T.

12. *X-Rays and N-Rays;* by R. Blondlot.—* * * * The consideration of the kind of symmetry belonging to a Crookes' tube suggested to me the possibility that the rays emitted by it might be polarized on their emission. I proved, in fact, that a small electric spark, subjected to their action, increased in brilliancy when the discharge was parallel to the axis of a Crookes' tube, and that this reinforcement did not take place when normal to the axis. This indicated that the rays emitted had indeed the want of symmetry characteristic of polarization. This point established, I demonstrated at once the existence of rotatory polarization: quartz, sugar, etc., served to rotate the plane of polarization of the radiations produced by a Crookes' tube. I then conceived the idea of trying the rotation by a series of mica plates, after the manner of Reusch: this rotation in fact took place. I was thus led to examine the effect of a single lamina

of mica: this gave elliptic polarization. But the facts stated proved the existence of double refraction and made *à fortiori* simple refraction highly probable. I proved then further that the radiations which I had studied were really deviated by a quartz prism and could be concentrated by a lens; it was also shown that they were reflected by a plate of smooth glass and diffused by an unpolished glass surface.

The facts stated indicate that the rays under examination were not Roentgen rays or X-rays, which suffer neither reflection nor refraction, but a new kind of rays traversing aluminium, wood, black paper, etc., polarized rectilineally on emission, susceptible of rotatory and elliptical polarization, and reflected or diffused, but producing neither fluorescence nor photographic action. To this kind of radiation I gave the name of *N-rays*. It is to the N-rays, in fact, that the phenomena of polarization pertain which I had observed and at first attributed to X-rays. If we analyze by a quartz prism the complex of rays emitted by a Crookes' tube, it is found that the X-rays are not deviated while the N-rays are deflected toward the base of the prism. It is easy then to prove that the N-rays alone act on a small spark while the X-rays seem to have no action on it. I have thus established the polarization of the N-rays and not that of the X-rays; also the velocity of propagation, which I have measured by a method published in these *Archives*, belongs not to the X-rays but to the N-rays. The confusion was unavoidable until the existence of the new radiations was recognized.

A further study of the N-rays has enabled me to prove that any source of light of very small intensity may be employed to show their existence, as a small gas flame, a platinum wire at a red heat, a phosphorescent screen. All of these sources of light have their brilliancy increased by the action of N-rays. A Crookes' tube is not the only source of N-rays; they are emitted also by an electric arc, a Nernst lamp, an Aner burner, and most of all by the sun.

The reflection and refraction of the N-rays follow the same laws as those of light; in particular the law of Descarlis has been verified with a high degree of precision in the experiments made with prisms and lens (of aluminium). In the emission from a Nernst lamp I have proved the existence of a large number of radiations of different indices comprised between the values 1·04 and 1·85. I have isolated the different pencils by the aid of an aluminium prism, I have measured their wave-length by the aid of *reseaux* traced on glass by the classic method, and the method, based upon the use of Newton's rings, has given results agreeing with the preceding. The wave-lengths are comprised between $0^{\mu}\cdot0081$ for the index 1·04 and $0^{\mu}\cdot0176$ for the index 1·85.

It follows from what has preceded that the N-rays are completely analogous to light, from which they differ only in the lengths of the waves, which are much shorter. Now light, ultra-

violet radiation, infra-red radiation and the Hertz radiations, which according to the electro-magnetic theory of light are an extension of light radiations, are propagated with one and the same velocity. In other words, there is a velocity of propagation common to all kinds of radiation and independent of the wave-length. It is thus, as it were, certain *à priori* that the N-rays, all of whose properties approach those of light, and which are surely a variety of it, should have the same velocity. This is precisely what the experiments already described in these *Archives* show. This verification of a fact reasonably sure in advance seems to me not without interest; it confirms the complete unity of character of what we now call the N-rays.—*Archives des Sciences, phys. et nat.*, Geneva, xvii, May, 1904.

13. *Lehrbuch der Physik;* von O. D. CHWOLSON; übersetzt von H. PFLAUM. Bd II., pp. xxii+1056. (Braunschweig: F. Vieweg und Sohn.)—The second volume of this work presents the same admirable qualities as the first volume, which has been previously reviewed in this Journal.* It comprises the subjects of sound and light and is an exhaustive presentation of the phenomena and, so far as is possible with elementary mathematical methods, of the theory also. The descriptive portions are exceedingly clear, the perspective good, and the arrangement so logical that, notwithstanding the great number of details presented, the treatment of the various subjects has a unity somewhat rare in works of this character. A very useful feature is the list, at the end of each chapter, of important original papers bearing upon the subjects treated in the chapter. H. A. B.

14. *Applications of the Kinetic Theory;* by W. P. BOYNTON. pp. x+288. New York. (The Macmillan Co.)—This is a well-arranged collection of the principal theorems and applications of the Kinetic Theory, in which physical ideas are not lost sight of by over emphasis upon the mathematical details. The treatment is, in the main, elementary and the methods employed are those of the founders of the theory, rather than the more general ones developed by Boltzmann and other recent writers upon the subject. The author has succeeded in giving a fairly complete account of the subject without assuming a very extensive acquaintance, on the part of his readers, with mathematics and mechanics; he has avoided the discussion of logical subtleties and delicate questions of rigor which occupy much attention at present, but which the beginner can well afford to do without. The successive chapters deal with ideal gases, gases whose molecules have dimensions, diffusion and viscosity, change of state, the equation of van der Waals, vaporization, liquids, solution, dissociation and condensation, and a summary containing numerical applications, etc. A knowledge of empirical thermodynamics is not assumed, but is given in the text when it is necessary for a comparison between the results of the theory and those of experiment. H. A. B.

* See volume xv, p. 82, Jan. 1903.

15. *Entropy; or Thermodynamics from an Engineer's Standpoint, and the Reversibility of Thermodynamics;* by James Swinburne. Westminster. Pp. x + 137. (Archibald Constable and Co.)—This book is the outcome of discussion carried on by the author and others during the latter part of 1903 in the columns of the London Engineering. This discussion has been of great value in calling renewed attention to the importance and difficulties of the thermodynamics of irreversible changes. Mr. Swinburne's contribution cannot, however, be said to be thoroughly satisfactory, unless considered alone for its suggestiveness, and for its rather amusing polemical rigor. In order to put more emphasis on irreversible changes, which are the only real changes occurring in nature, and in order to gain a more physical notion of entropy, he proposes a new order of development of the principles of the science. That these praiseworthy objects have been successfully attained seems doubtful, though the suggestiveness arising from the change in viewpoint cannot fail to be of value to the thoughful reader. The accepted or orthodox (as Mr. Swinburne for controversial purposes prefers to call it) presentation of the science starts with those laws of the transformation of energy which are known as the two laws of thermodynamics; then comes the consideration of the reversible process and cycle from which, by application of the second law, we get the idea of entropy and its conservation; then passing to irreversible or actual processes, we arrive at the notion of the waste in such processes and the growth of entropy. The presentation proposed in this book starts, as does the ordinary treatment, with the same two laws of energy transformation, though Mr. Swinburne unnecessarily mars the presentation by inserting a wholly gratuitous third law, i. e. that a frictionless mechanism is unrealisable; then follows the consideration of the irreversible or actual process, the waste incurred in such processes, the definition of entropy as the measure of the waste, and the doctrine of the growth of entropy; then taking up the ideal reversible cycle, the working definition or mathematical expression for the entropy (or rather for its minimum value) is obtained. Now, aside from the pugnacious manner in which it is presented, and leaving out the unessential and unfortunate "third" law, there can be no valid objection to looking at thermodynamics in this way if one so wishes; in fact, the reviewer feels under a great personal obligation to Mr. Swinburne for proposing this very suggestive alternative viewpoint. When, however, he comes, in the third and fourth chapters, to consider in detail certain irreversible changes, one cannot criticise the author so favorably. There is a lamentable confusion in the matter of the "heat of a body," and, in particular, the restriction of the temperature, in the expression for entropy to the temperature of the envelope, cannot be admitted. A criticism of less moment is that Mr. Swinburne's contention that the state of development of a science is a function of the names it possesses for its units, and that therefore thermodynamics will continue in

a backward condition until his proposal of the "claus" for the unit of entropy is adopted, appears more amusing than convincing.

In conclusion, it may be said that the wish expressed in the last paragraph of the appendix—"that the somewhat novel way of arranging and treating the subject-matter of the groundwork of thermodynamics may meet with the approval of those who specially deal with that science"—will perhaps see a fair measure of fulfillment. The remainder of the subject matter illustrates, in a manner unfortunately not rare, the statement made at the end of the fourth chapter, that thermodynamics "is perhaps the most slippery branch of science there is." L. P. W.

16. *Electricity and Matter;* by J. J. Thomson, 162 pp. New York, 1904 (Charles Scribner's Sons).—This volume gives in full the six lectures delivered by Professor Thomson at Yale University, on the Silliman foundation, in May, 1903. Those who were so fortunate as to hear this most interesting and suggestive discussion of the nature of electricity and constitution of matter, by one whose own contributions have been of the first importance, will be glad to have the lectures preserved for them in permanent form. The volume also serves the more important end of enabling the gifted lecturer to reach a much larger audience; this, indeed, should include all those who are interested in the progress of science and who, at the same time, have some basis of physical knowledge to make their reading intelligent.

17. *Étude sur les Resonances dans les Réseaux de distribution par Courants alternatifs;* par G. Chevrier. 76 pp. Paris, 1904 (édité par l'Éclairage Electrique).—This is a systematic and homogeneous presentation of a subject, the various aspects of which have been discussed by numerous authors from different points of view. The theory of oscillatory movements in general is given first, followed by a presentation of the theory specialized for the case of circuits with capacity and self-induction. The third part gives the application of the results obtained to the condition of the practical current.

18. *Elektrische Fernphotographie und Ähnliches;* von Dr. Arthur Korn. 66 pp. Leipzig, 1904 (S. Hirzel).—The author here reproduces three memoirs, recently published in the *Physikalische Zeitschrift*, giving an exact description of his methods and apparatus; a historical introduction is added. Those who have not kept up with the progress in this interesting line of experiment will be surprised to see what can now be accomplished.

19. *The Telescope;* by Thomas Nolan. Second edition, revised and enlarged, 128 pp., 12mo. New York, 1904 (D. Van Nostrand Company).—To the matter contained in the first edition of this little book, there has been added a new chapter describing the advances made since 1880 and, following this, a bibliography of the important literature on the telescope. The author has succeeded in setting before the reader a large amount of interesting information simply presented and in a very small space.

20. *Scientia, Phys. Mathématique,* No. 23. Paris, 1904 (C. Naud).—This recent number of the valuable series of scientific memoirs now being published in Paris is by H. Poincaré, and is devoted to the subject of the theory of Maxwell and the oscillations of Hertz, with their application to wireless telegraphy. It is an excellent presentation of a very interesting subject.

II. Geology and Natural History.

1. *Glacial Conglomerate, Transvaal, South Africa.*—A proof sheet recently received from the Geological Society of South Africa announces the discovery by E. T. Mellor of extensive glaciated surfaces and deposits 25 miles east of Pretoria. The deposits represent the lower portion of the Highveld Formation, lying immediately below the Coal Measures and "consist of irregularly alternating, usually more or less lenticular deposits of conglomerates, sandstones, and shales. The conglomerates have all the characters usual to ground-moraines. They contain an assemblage of bowlders very miscellaneous in composition and size, embedded in a clayey, or more frequently sandy, matrix full of smaller angular rock fragments. Bedding planes are rarely met with. The bowlders are polished, facetted, and in the case of those composed of material sufficiently fine in grain, frequently striated. The sandstones are also very irregular in thickness, often massive and without traces of bedding; they are white, yellow, or cream-colored, and though often fine in texture, very rough to the touch. The shales are white or cream-colored. They frequently show fine lamination, very regular over short distances, but not persistent over any considerable area. More frequently they partake of the nature of mudstones. These shales are more abundantly developed near the upper portion of the glacial series."

"The glacial deposits were laid down upon a land surface of considerable variety, many features of which reappear with slight modification in the landscape of to-day." Wherever the glaciated deposits are removed by erosion, glaciated surfaces are of frequent occurrence. The striae and bowlders alike abundantly prove that the ice movement was N.N.W. to S.S.E. This direction is in accord with the observations of Rogers and Schwartz at Prieska, Cape Colony (Ann. Report Geol. Com. 1899) and of Schenck near the junction of the Orange and Vaal Rivers (Ueber Glacialerscheinungen in Süd Afrika), but not with the observations of Molengraaff in the Vryheid district (Trans. Geol. Soc. of S. A., IV, pt. V, 1898). The wide extent of the glacial deposits, their presence at various elevations, and the parallelism and constancy of direction of the striae in the Transvaal locality indicates a considerable thickness for the ice sheet.

2. *Wisconsin Geological and Natural History Survey.* E. A. Birge, Director.—Two bulletins of the Wisconsin Survey have recently been published.

Bulletin No. XI.—Preliminary Report on the Soils and Agricultural Conditions of North Central Wisconsin; by Samuel

WEIDMAN. 64 pp., 10 pls., including soil map.—The different classes of glacial drift constitute the principal part of the surface outcrops of Central Wisconsin and these formations are described in detail as to character, water content, etc. Climatic conditions are discussed in Chapter III, (pp. 49–64).

BULLETIN XII.—The Plankton of Lake Winnebago and Green Lake; by G. DWIGHT MARSH. 89 pp., 22 pls.—A comparative study of the Plankton of two lakes of different types has been carried on for a considerable time and many facts regarding the annual and geographical distribution of the animals and plants have been secured. The principles controlling distribution are also discussed.

3. *Geological Survey of Ohio.* EDWARD ORTON, JR., State Geologist. Fourth Series, Bulletin 1. The Occurrence and Exploitation of Petroleum and Natural Gas in Ohio; by J. A. BOWNOCKER. 320 pp., 6 pls., 10 maps.—The history of the Ohio Geological Survey is divided into four distinct periods: 1837–1838, when in charge of W. W. Mather; 1869–1888 under J. S. Newberry and Edward Orton; 1889–1894 when the scope of the survey was somewhat extended, but still in charge of Edward Orton; 1900—when the present State Geologist was appointed and a reasonable appropriation granted by the General Assembly. The investigations now in progress are a revision of the areal and stratigraphical geology, by C. S. PROSSER; and a study of the cement, lime, brick, salt and coal industries by various specialists. The first publication issued by the fourth survey is an elaborate detailed discussion of the history, development, utilization, and future prospects of the oil and gas industry of the state. The descriptions are by townships and include a mass of local geological detail. The origin of oil and gas is discussed in a separate chapter.

4. *Geological Survey of New Jersey,* HENRY B. KÜMMEL, State Geologist. Annual Report, 1903. 128 pp., 14 pls.—The work of the New Jersey Survey shows progress along several lines of activity. It has been decided to replace the present topographic map with a new system of non-overlapping sheets. Professor Salisbury is to prepare a report on the surface geology of the southern part of the state. Dr. Weller reports that the Cretaceous presents definitely recognizable faunal zones traceable entirely across the state. Dr. Eastman has made arrangements to complete his studies of the Triassic fish at once. In addition to the usual reports on underground water, mineral resources, etc., a special report is made by C. C. Vermeule on the Passaic floods and a scheme for their control by a throttling dam at Little Falls.

5. *Delta Plains in the Nashua Valley.*—The extensive excavations and borings made by the Metropolitan Water Board in the region of glacial Lake Nashua have furnished unusual opportunities for the study of glacial deposition. In the Technology Quarterly, xvii, No. 1, W. O. CROSBY describes in detail the structure and composition of the delta plains of the Clinton stage and their associated deposits.

6. *The Floods of the Spring of 1903 in the Mississippi Watershed;* by H. C. Frankenfield. U. S. Weather Bureau Bulletin M, 63 pp., 15 charts.—The Mississippi Floods of 1903 exceeded in height any high water on record from Memphis to the Passes. The greatest destruction was at Kansas City, but the villages along most of the western tributaries of the Missouri were affected. As a study of abnormal rainfall and run-off this bulletin is of much value.

7. *Catalogue of the Ward-Coonley Collection of Meteorites;* by Henry A. Ward. 113 pp. with 10 plates. Chicago, 1904.—It is certainly most remarkable in the history of meteorites that a collection, which is now the largest in the world in number of falls and stands in the first rank with the great collections of Vienna, London and Paris, should have been brought together through the activity and enterprise of one collector and that within a period of ten years. This is true, however, of the Ward-Coonley Collection, the third catalogue of which is now issued. Mr. Ward had already brought together two earlier collections of 170 and 200 falls, respectively, and it was not until 1894 that the present collection was begun. It now numbers 603 falls, with a total weight of about 2500 kilos. During the past four years the increase has been at the rate of 45 falls per year; the catalogue of 1900 showed 424 falls (1399 kilos) and that of 1901 gave 511 falls (1786 kilos). The collection is not simply remarkable in the number of occurrences, but also in the relatively large size of many of the individual specimens. A list, for example, is given of 30 falls, about equally divided between irons and stones, of which the largest single piece is now preserved in the Ward-Coonley Collection. In addition to this point, the introduction of the catalogue calls attention also to some of the remarkable features of the individual specimens and deserves to be studied in detail. The collection is at present placed on deposit in the Geological Hall of the American Museum of Natural History in New York City. The catalogue is handsomely printed, giving not only the locality, details in regard to weight, etc., but also the character of each specimen, as indicated on the scheme of Brezina detailed on a later page. In addition to the main chronological list of the collection, an alphabetical list of all known meteorites with synonyms is given, also a list showing geographical distribution. A series of half-tone plates show some noteworthy specimens, also representations of a number of polished surfaces of the irons, with the figures developed by etching.

8. *Harvard Experiment Station in Cuba.* G. L. Goodale.—The generosity of Mr. Edwin F. Atkins, of Boston, has placed at the service of the Botanical Department of Harvard University a tract of land and certain buildings near Cienfuegos, which are now employed actively in the attempted solution of a few problems in applied botany. The grounds were first utilized for this purpose a few years ago, when preliminary trials in the artificial production of sugar cane seed were undertaken. For a

short time previous to this, an extensive collection of all the approved varieties of cane then accessible was brought together, and this has been enlarged from time to time, until the sorts now have a very wide range.

From the outset, a good deal of attention was paid to the acquisition of the best kinds of other useful plants, especially those which are adapted to the tropics or those northern plants which can be made to grow more luxuriantly in very warm regions. The establishment was so fortunate as to secure early the services of Mr. C. G. Pringle, as botanical collector. He has devoted much time, with good success, to the selection and forwarding of desirable species from Mexico.

By the end of last year, the number of species had increased so considerably that a new and thoroughly skilled superintendent was placed in charge of the grounds. Mr. Robert M. Grey, the new superintendent, is widely and favorably known as an accomplished hybridizer. He has had placed at his disposal ample facilities for prosecuting his experiments in many directions.

The principal directions of these researches are the following:

(1) Securing the best varieties of cane, by selection and by seeds. In this part of the work, the fullest opportunity is given for the prompt and exact determination in the chemical laboratory of the station, of the sugar-content. Some of the more interesting results have already been published.

(2) Selection and improvement of cotton, ricinus, pineapple, etc., with definite relation to the resistant power of the varieties.

(3) The cultivation of the line of vegetables demanded by the large estates, and finding also a ready market in the cities. This line of study has proved useful and is likely to be more and more highly appreciated by the smaller cultivators with limited capital. This series of studies is placed on an exact basis with regard to cost and profit, in order that the results may be a safe guide to the small farmers and gardeners.

One of the most useful functions of the station has been to show the necessity of extreme caution in entering on large plantings of certain plants which have relentless enemies in the neighborhood, for instance, as a special case, cotton of the usual sorts.

The station was visited winter before last by Mr. J. C. Willis, director of the Royal Botanic Gardens at Perideniya, Ceylon, who has aided us much by his advice. From many sources most generous coöperation has been obtained, and the interesting experiment is now fairly in hand. To indicate somewhat more fully the general nature of the enterprise, I select portions from the latest report of Mr. Grey, which refer especially to the sugar cane, caladiums, pineapples and ricinus.

9. *Report of the Harvard Botanical Station in Cuba for the Month of May, 1904;* by Robert M. Grey.—The meteorological observations for the month are as follows: temperature max., day 91°, min. 73°; night 76° and 64°; humidity of the atmosphere 85° to 100°; rainfall 18·04″, for May, 1903, 8·14″.

During the month of May the temperature has been below normal, usually ranging between 82° and 87°, never above 90° during the hottest part of the day. The mornings and evenings have been cool and pleasant with a fine breeze, south to southeast winds prevailing. The barometer has been steady, ranging from 29·87″ to 29·90″. The humidity of the atmosphere has been greater than for the month previous.

The rainfall for the month has been abnormally large. A heavy storm of May 1st lasted about twenty hours, during which time 5·50″ fell, swelling the arroyas and streams to an enormous height, washing out some of the spring planting, and causing much extra work in the garden, which suffered severely. The stream rose eight feet, carrying away some of our botanical plants, which were situated along its margin, and many choice lilies, besides the represser and one bridge. Another severe rainstorm of 4·04″ visited us on May 7, causing a still greater flood, ruining completely bridges, walks and nearly everything along the water course, including our stock Platinal of about ten varieties, some pineapples, fancy caladiums, a part of the tea, Liberian coffee, cocoa, callas, etc.

. . . . Special effort is devoted to propagating, weeding, cleaning and planting shrubbery in our new nursery. We already have a fair lot of laurels, crotons, acalyphas, limes, and about five hundred roses planted out, and much small stock of various kinds which will be transferred later.

The sudden change from dry to wet weather has caused black spot among a few things, such as roses, lettuce, and other stock.

Among the quantities of sugar cane seeds sown this season (over four hundred heads) we have had very poor results. Probably not more than eight or ten seeds in all germinated, and, excepting a single plant, which is still too young to determine positively, these have all died. The remaining one is making a good growth. It came up among seeds of Crystallina collected among the Cinta in the "Chino" and without artificial hybridization. A small portion, each of one hundred heads, was selected and planted together in our small Platinal (since injured by water). The plant germinated about April 27. It has grown rapidly and is now about four inches high, with three fairly characteristic leaves.

I am of the opinion that Cuba is the northern boundary where sugar cane produces flowers, and it therefore seldom perfects seeds of good germinating power in Florida and Louisiana; very little farther north it does not even flower. The flowers on our cane here are perfect and the seeds in many cases reach normal size and appear good, but are very soft and delicate. They are, however, a month later than in the more southern warmer islands and thus do not always have the benefit of the late fall rains to perfect them; no doubt, however, in a succession of years we shall occasionally find favorable seasons in which better luck may attend our efforts.

The new spring plantings of experimental canes came up regular and healthy and are growing well. The varieties of which we had but one or two stock plants have been divided up and transplanted with the rest of the collection, thus bringing all of the experimental canes together in one patch. Since the arrival of the wet weather, what appeared to be "Sereh" or Fan disease on one or two of our Java canes has disappeared, the fanlike appearance being nothing more than stunted growth. Several, however, which showed a lack of chlorophyl in the leaves and were sickly in the roots (probably through weakness) have not grown out of it and will be destroyed as a preventive.

Careful observation among the cane in the field has not brought to light disease of any kind; several plants which had "Rind Fungus" on the dead stock during the early spring and which were marked by us, upon careful examination fail to show traces of any disease in the young canes. They are perfectly healthy and vigorous, which I believe conclusively indicates that the Rind-disease fungus takes possession of dead tissues in exhausted or dead canes when of no further use to the plant.

On December 4, I cross-hybridized Red Spanish and Cuban Queen pineapples; on May 18, when the fruit ripened, I found that not one had perfected any seed. This may be due to the dry season, and I shall experiment further during the wet season when flowers again begin to open. We have disbudded a large per cent of the Cuban Queen pineapples and a great improvement is discernible. The fruits grow larger and mature more rapidly, the flavor is improved and the tissue is softer. This variety usually produces ten to twenty shoots around the base of the fruit, which continue to grow and rob them of the sap essential to their proper perfection. Where disbudding is not resorted to (at least in the winter crop) they take a much longer time to ripen, and they lack flavor.

Colacasia antiquorum, known here under the name of "Malanga" or Tania, is one of the principal articles of food. It is boiled in a similar way to sweet potatoes or "Bonata" and much preferred to it. There are three distinctly marked varieties. The type has dull glaucous green leaves and stems somewhat tinged with purple, and the leaves are rather sharply defined. This is the one commonly cultivated in this vicinity. It is rather insipid in flavor and does not multiply very quickly in the field. The Castilian Malanga, Colocasia antiquorum var. esculentum, is identical with our northern Caladium esculentum; it is of a yellowish color, has a sweetish flavor when cooked, and is much preferred by the laborers. The plant is a stronger and more rapid grower, the leaves are large, irregular, pale green, scarcely glaucous, and the leaf stock is only faintly glaucous. It produces from one-third to one-half more "bulblets" per annum. After giving these two varieties a fair trial I am convinced that the old type can be gradually discarded in favor of this one, and have set out about five thousand in the soltadera for the coming

season, along with as many of the others. They already show a superior growth. This variety is also a valuable florists' plant, and large "bulbs" bring a good price in the market; they could, if desired, be grown here in quantity and at a very fair profit.

The third variety is at present rather scarce, it is a larger and taller grower than either of the above sorts, with a vigorous constitution, but makes very few offsets and does not perfect them so quickly; the flavor is also rather inferior to C. esculentum. The fancy bright foliage Caladiums (closely related to the above) of the C. Schomburgkii, C. Marmoratum, C. bicolor, and C. picturatum type with their hybrids and varieties, grow and increase freely here, and although the market is somewhat limited they can be profitably grown. They do best in a rich humus and require some shade in order to mature big "bulbs" quickly.

The castor-oil plants (Ricinus Zanzibariensis var. Nigra) sowed January 10 ripened their first fruit May 29, and promise a good crop. This is the large black African bean; it is not quite so high in percent of oil as the small native bean, but is several times larger, superior in every other respect, and equally productive, which will more than compensate for this slight difference. The shell is softer and more easily crushed and pressed than the native variety; it also has an advantage over nearly all other varieties in the fact that it is self-shelling in either fire or sunheat, while the native one is not. As a proof of this, I took samples from thirty separate plants and did not find one in which they were self-shelling. Some of the varieties of Arborea and Borboniensis are better in this respect, but I have not been able to test them thoroughly yet.

[The remainder of the report deals with cotton, and with certain vegetables.]

10. *Catalogus Mammalium, tam viventium quam fossilium;* a Doctore E.-L. Trouessart. Quinquennale Supplementum, Anno 1904. Fasc. I, pp. iv, 288. Berlin (R. Friedländer u. Sohn).—The successive parts of the second edition of this great work have been repeatedly noticed in these pages. The edition was completed in 1897 and an appendix was issued in 1899. A new method has now been adopted to bring the work up to date, viz., the publication of a five-year supplement complete in itself and forming, in fact, a third volume of the *Catalogus;* of this supplement the first part is now issued. The arrangement is such as to show at once what new species have been added and to what groups they belong.

III. Miscellaneous Scientific Intelligence.

1. *Publication of the Earthquake Investigation Committee in Foreign Languages*, No. 16, 117 pp. Tokyo, 1904.—A detailed discussion is here given by A. Imamura of the Milne horizontal pendulum seismograms obtained at Hongo, Tokyo, of earthquakes, about 300 in number, which occurred from July, 1899, to Dec., 1902. Of 49 large earthquakes, 30 of which originated

outside of Japan (East India, Gulf of Mexico, Alaska, etc.), and 19 within Japan, the majority were submarine, only two of the Japan earthquakes having been inland ones. From the observation of these large earthquakes, the average transit velocities of the different phases obtained are as follows: $V_1=13{\cdot}2$ km. per sec., $V_2=6{\cdot}8$, $V_3=4{\cdot}5$, $V_5=3{\cdot}3$, $V_6=2{\cdot}8$, $V_7=2{\cdot}4$, $V_8=2{\cdot}1$.

2. *Ready Reference Tables,* Volume I. Conversion factors of every unit or measure in use, including those of length, surface, volume, capacity, weight and length, etc., based on the accurate legal standard values of the United States. Conveniently arranged for engineers, physicists, students, merchants, etc.; by CARL HERING, M.E. 16mo, pp. xviii + 196. New York, 1904 (John Wiley & Sons).—The great value to the practical worker of a volume of tables, such as the present, is so obvious that it hardly needs to be insisted upon. The arrangement and typography here are excellent, while the condensed list on the opening pages and the index add much to convenience of use.

3. *University of Chicago: Decennial Publications.*—The first series of these publications consist of ten quarto volumes, viz.: two volumes of reports and eight volumes of investigations representing the research work in the different departments of the University. From volume ix, devoted to mathematics, physics, chemistry, geology, the following memoir, recently issued, is separately printed: The subgroups of the generalized finite modular group, by Eliakim Hastings Moore.

4. *Field Columbian Museum.*—Recent publications include the following: No. 2 of vol. III of the Botanical Series, by Charles Frederick Millspaugh and Agnes Chase, devoted to the plants (Compositæ) of the Peninsula of Yucatan; No. 16, vol. III, Zoological Series, by D. G. Elliot, on mammals collected in Southern California by E. Heller; also No. 3, vol. II, Report Series, giving the Annual Report of the Director for 1902–03.

5. *Publications of the Bureau of Government Laboratories at Manila.*—Bulletin No. 1 of the Entomological Division of the Biological Laboratory, by Charles S. Banks, entomologist, recently issued, discusses the Insects of the Cacao, especially for the benefit of farmers.

OBITUARY.

SIR CLEMENT LE NEVE FOSTER, F.R.S., professor of mining in the Royal College of Science in London, died on April 19, at the age of sixty-three years.

PROFESSOR ALEXANDER W. WILLIAMSON, the venerable English chemist, died on May 6, at the age of eighty years.

MR. FRANK RUTLEY, the well known English petrologist, died on May 16 at the age of sixty-two years.

PROFESSOR ÉMILE DUCLAUX, the eminent French bacteriologist, died early in May in his sixty-fourth year.

PROFESSOR CHARLES SORET, of Geneva, well known for his work in experimental physics, died on April 5th, at the age of fifty years.

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Established by BENJAMIN SILLIMAN in 1818.

THE

AMERICAN JOURNAL OF SCIENCE.

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FOURTH SERIES.

VOL. XVIII—[WHOLE NUMBER, CLXVIII.]

No. 104.—AUGUST, 1904.

WITH PLATES I–IV.

NEW HAVEN, CONNECTICUT.
1904

THE TUTTLE, MOREHOUSE & TAYLOR CO., PRINTERS, 123 TEMPLE STREET.

Published monthly. Six dollars per year, in advance. $6.40 to countries in the Postal Union. Remittances should be made either by money orders, registered letters, or bank checks (preferably on New York banks).

THE

AMERICAN JOURNAL OF SCIENCE

[FOURTH SERIES.]

Art. XIV.—*On the Ratio of Radium to Uranium in some Minerals;* by Bertram B. Boltwood.

The experiments which will be described in this paper were undertaken with the object of determining the relative proportions of radium and uranium present in certain mineral substances.*

The method which has been used for the quantitative estimation of the radium depends upon the electrical measurement of the radium emanation which is given off when a known quantity of the mineral is dissolved or decomposed by suitable chemical reagents and this solution is allowed to stand for several days in direct communication with a closed glass vessel. Another plan which has also been tried is to decompose the mineral completely in an open vessel and to heat the solution to boiling in order to expel all of the accumulated emanation. The solution was then sealed up in a closed glass vessel and the emanation allowed to accumulate for a given period, at the end of which it was removed and measured†.

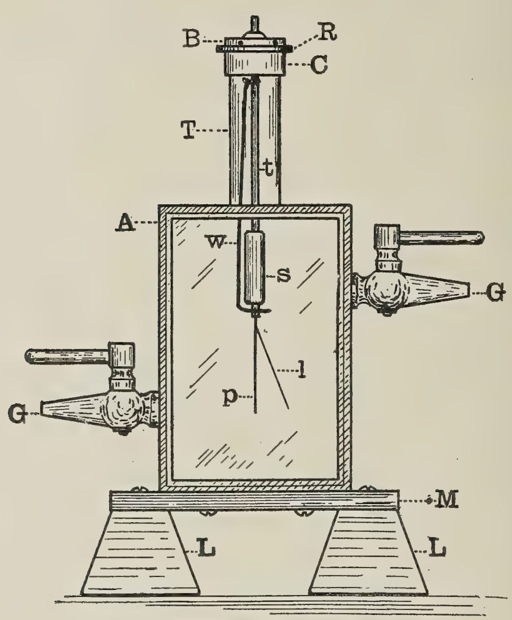
The testing of the emanation was carried out in an air-tight electroscope (fig. 1) similar in principle and design to that described by C. T. R. Wilson. It consisted of a rectangular brass case *A*, 15^{cm} high, 10^{cm} wide and $4{\cdot}5^{cm}$ deep. The

*A preliminary notice in which some of the results were given has already appeared in the Engineering and Mining Journal, lxxvii, p. 756, and in the London Nature, lxx, p. 80.

† In a paper by Strutt (Proc. Royal Soc., lxxiii) some measurements of the amounts of radium emanation given off by certain minerals on heating are described. Some experiments which I have made show that samarskite, on heating to low redness, gives off only 10 per cent, and on heating to bright redness only 20 per cent, of the emanation set free when this mineral is completely decomposed with hot sulphuric acid.

walls of this case were 6^{mm} in thickness and were grooved on the edge to a depth and width of 3^{mm}. Two plates of plate-glass 3^{mm} thick fitted closely into the grooves of the case and the joint was made air-tight by the use of hot sealing-wax. The glass plates formed the front and back of the electroscope case. The case was provided with two brass stopcocks, *G*, and carried on the top a glass tube *T*, $2{\cdot}5^{cm}$ in diameter and $7{\cdot}5^{cm}$ in length. The gold-leaf, *l*, was attached to the brass plate *p*, which was 5^{cm} long and 1^{cm} wide, and was soldered to a brass

1



rod $1{\cdot}5^{cm}$ long and 3^{mm} in diameter. The rod *s* of cast sulphur, 4^{cm} long and 1^{cm} in diameter, served as an insulating support for the gold-leaf and was attached at the top to a brass rod 12^{cm} in length and 3^{mm} in diameter. The brass rods were connected firmly to the sulphur support by warming the rods to above the melting point of sulphur and pushing them a short distance into the ends of the sulphur rod. Fitted to the top of the tube *T* was a brass ring, *C*, into which screwed the cap *B*, also of brass. Through the latter passed a short glass tube 1^{cm} in diameter and contracted somewhat at the top. This glass tube was filled with melted sulphur, which was then allowed to solidify. The end of the rod *t* was then warmed and pushed through the sulphur plug until it extended about 5^{mm} beyond

it, and the joint was made still tighter by the application of a small quantity of melted sealing-wax. Suspended by a small hook near the top of the rod t was a soft iron wire w, which extended to below the sulphur rod and terminated in a loop which surrounded the rod supporting the plate p. When hanging in its normal position this wire did not touch the lower rod, but on bringing a small magnet near the tube T the wire was deflected and established a metallic circuit between the upper rod and the gold leaf. The plate p and the metal portions of its supports were heavily gold-plated to prevent tarnishing. All of the joints and crevices were filled with sealing wax except that between B and C, which was closed air-tight by a rubber washer, R, between them. By unscrewing the cap B the gold-leaf and its supports could be removed from the case.

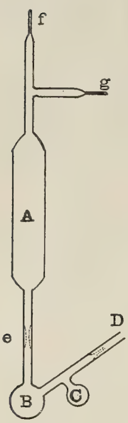
The electroscope was attached by screws to an iron plate, M, which in turn was fastened to two lead ingots, L, L, weighing about seven pounds each. The whole apparatus was therefore very steady and connections could be made at the cocks without fear of altering the adjustment.

For charging the gold-leaf a large stick of sealing-wax was used. This was rubbed lightly on the clothing and approached to the top of the rod t, the wire w being brought at the same time into contact with the plate p by means of a small magnet. On rubbing the rod gently with the sealing-wax a sufficient charge was imparted to the gold leaf to produce the desired deflection. After removing the sealing-wax stick and the magnet, the top of the rod and cap were touched with the finger. This method of charging worked very well during the dry weather of winter and early spring but became troublesome when the air of the laboratory grew moister, and has therefore been superseded by the use of a battery of small storage cells giving a potential of from 300 to 400 volts.

The fall of the gold-leaf due to leak of the electric charge was observed by means of a microscope mounted on a separate support in front of the electroscope. This microscope consisted of a Bausch and Lomb combination of a 2-inch eye-piece and a 1½-inch objective mounted in an ordinary draw-tube. The diameter of the field was about 4^{mm} and the eye-piece contained a glass scale divided into nine divisions, which were further subdivided into tenths; each tenth of a division therefore corresponded to about $0{\cdot}044^{mm}$.

The radium emanation given off by a known weight of mineral substance was collected in the apparatus shown in fig. 2. This was made entirely of glass and consisted of an elongated bulb, A, connected by a tube with the smaller bulb B, which in turn was connected with the still smaller bulb C. A weighed

quantity of the very finely powdered mineral was introduced from a long, thin weighing-tube into the bulb *B*, and, except where the reagent afterwards employed was concentrated sulphuric acid, enough water to cover the mineral was then introduced into *B* from a small pipette. *C* was then filled with the acid used to decompose or dissolve the mineral and, the capillary tubes at *f* and *g* having been already closed, the tube *CD* was drawn out into a short capillary and sealed off in the flame of a blast-lamp. At the moment of sealing off, a slight negative pressure was created in the interior of the apparatus by drawing out a small portion of the air through a rubber tube attached at *D*.



2

The apparatus was tipped until the acid in *C* ran over into *B*, and *B* was then warmed gently until the mineral contained in it had been entirely decomposed. The apparatus was then allowed to stand undisturbed for several days to come into equilibrium and the tube connecting *A* and *B* was then drawn out into a short capillary and sealed off at *e*. The bulb *A*, separated in this manner from the rest of the apparatus, was then allowed to stand for about two hours in order that any rapidly decaying emanation (thorium or actinium) might be entirely removed. The air and radium emanation contained in *A* were then transferred to the electroscope in the following manner: The capillary tube at *e* was first notched with a file and then broken off under the surface of a strong sodium hydroxide solution. Because of the diminished pressure in *A*, several cubic centimeters of the sodium hydroxide solution would be drawn into the bulb. A short rubber tube filled with water was then slipped over *e*. The other end of this rubber tube dipped into a vessel of water. A closed screw pinchcock was then attached to the rubber tube near *e* and the bulb *A* was tilted so that its interior walls were completely wetted with the sodium hydroxide solution. This served to dry the gas somewhat and to remove any acid fumes which might be present. The pressure on the interior of the electroscope was now exhausted to about one-half atmosphere and the stopcocks closed. The capillary tubes at *f* and *g* were notched with a file and *f* was connected with one of the stopcocks of the electroscope by a short section of rubber tubing. The pinchcock at *e* was then opened, the tip of the capillary tube *f* was broken off inside the rubber tube, the stopcock of the electroscope was opened slightly and the air in *A* was drawn over into the electroscope. When the water had risen in *A* until it had reached the junction of the side-tube *g*, the pinchcock at *e* was closed, the tip of *g* was

broken off and the external air was allowed to sweep through the system of tubes until the pressure within and without the electroscope was the same. The stopcock of the electroscope was then closed and the other apparatus disconnected.

For determining the rate of leak or discharge of the gold-leaf, measurements were made of the time required for the gold-leaf to fall through a distance equal to eight divisions of the scale in the eye-piece in the microscope. The time required was recorded by means of a stop-watch divided to fifths of a second. Because of the initial rise in the activity, due to the formation of induced activity within the electroscope, the rate of leak at the end of three hours was chosen in comparing the results obtained with different minerals.

In order to determine the quantity of uranium present in the mineral under examination, the solution in the bulb B was washed out into a beaker and the quantity of uranium determined by one of the ordinary methods of analysis.

The capacities of the two final sections of the apparatus were determined by filling them with water and weighing them, and then weighing them when empty. The average capacity of *A* in the different experiments was about 48^{cc} and the average capacity of the rest of the apparatus was about 9^{cc}. In comparing the results obtained with different minerals it was in general assumed that the distribution of the emanation throughout the different parts of the apparatus was uniform and the volume occupied by the solution was neglected. Since the capacities of the different pieces of apparatus used were in all cases approximately the same and the volumes of the different solutions were all approximately equal, this possibly doubtful assumption would cause no serious error in the results when used for purposes of comparison.

The results obtained with eight different samples of uranium minerals are given in a table below. For decomposing the uraninites strong hydrochloric acid containing a little nitric acid was used, the gummite and uranophane were treated with strong hydrochloric acid and the carnotite was dissolved in dilute (1 : 1) nitric acid. The sample of samarskite used was obtained in a very finely divided condition by suspension in water and decantation from the coarser material. In this form it could be readily decomposed with concentrated sulphuric acid.

The samples No. 1, 2, 3 and 4 were from North Carolina, No. 5 from Branchville, Conn., Nos. 6 and 7 from Colorado and No. 8 from Saxony.

Between experiments 5 and 6 the adjustment of the electroscope became slightly altered from an accidental movement of the microscope support. A re-determination of the constant

for sample No. 1 under these conditions gave the value of the ratio as 263.

No.	Substance.	Per cent uranium in mineral.	Grams uranium taken.	Leak divisions per min.	Ratio leak to uranium.
1	Uraninite	82·5	0·1067	22·5	211
2	Gummite	66·1	0·0982	20·8	212
3	Uranophane	46·6	0·0671	12·1	181
4	Samarskite	9·8	0·0299	6·4	214
5	Uraninite	83·9	0·0994	20·6	207
6	Carnotite	18·0	0·0258	6·9	267
7	Uraninite	54·6	0·0783	19·8	253
8	Uraninite	48·5	0·0699	16·5	231

The low value of the ratio in the experiment with No. 3 was at first attributed to the fact that this material appeared to give off in the cold a greater proportion of its emanation than the other minerals of the series and that it had, therefore, not reached a state of equilibrium at the time when the emanation was measured. A more careful measurement of the proportion of emanation lost by the cold pulverized samples was made and no differences sufficiently great to explain the low value in No. 3 were obtained. Since the solution of the uranophane had gelatinized on standing in the solution apparatus, owing to the relatively high proportion of silica which the mineral contains, it was thought that this might have been the cause of the low result. Small samples of Nos. 1, 2 and 3 were, therefore, completely decomposed with acids and the resulting solutions evaporated to dryness on the water-bath. The residues were treated with dilute hydrochloric acid and the solutions thus obtained were introduced into apparatus similar to the solution tubes (fig. 2) already described, except that the lower part consisted of a single bulb only. The solutions were then sealed up and allowed to stand for thirty days. At the end of this period the bulb *A* was sealed off and the accumulated emanation transferred to the electroscope. The results thus obtained are given in the following table:

No.	Substance.	Per cent uranium in mineral.	Grams uranium taken.	Leak divisions per min.	Ratio.
1	Uraninite	82·5	0·1227	16·6	135
2	Gummite	66·1	0·0964	13·3	138
3	Uranophane	46·6	0·0686	9·8	143

It is therefore probable that the low value obtained in the first experiment with the uranophane was due to the formation of gelatinous silica. The value of the ratio stands in no direct relation to that obtained in the other series, since the adjustment of the electroscope was again different.

The chief sources of error in the method as described are due to two causes. One of these lies in the fact that the heating of the tube connecting the bulb *A* with the bulb *B* naturally warms the gases contained within them and causes a slight alteration in their relative capacities. This difficulty was avoided as much as possible by wrapping both bulbs in wet filter paper before the tube connecting them was heated. The other possible error lies in the fact that some of the minerals tested, particularly Nos. 7 and 8, contained a considerable per cent of sulphides. On treating these minerals with the aqua regia necessary to decompose them, the sulphur of the sulphides was in part oxidized to sulphuric acid and a noticeable quantity of lead sulphate separated from the solution. Although radium sulphate is quite soluble in the strong aqua regia used, it is not impossible that slight traces of this compound were carried down by the precipitated lead sulphate. This would explain the lower values of the ratios obtained with 7 and 8.

I am particularly indebted to Prof. H. A. Bumstead of Yale University for valuable assistance and advice given in connection with this research, and to Prof. S. L. Penfield of Yale University and Dr. Joseph Hyde Pratt of Chapel Hill, N. C. for most generously supplying me with the minerals used in these experiments.

Conclusions.

The quantities of radium present in the uranium minerals which have been examined are apparently directly proportional to the quantities of uranium contained in the minerals.

Since it has been suggested by J. J. Thomson and Rutherford* as very probable that radium is formed by the breaking down of the uranium atom, and if such were the case a final state of equilibrium and a definite proportion between the uranium and radium present in minerals would be expected, these results seem to be of value in furnishing experimental evidence of the actual existence of this fixed relation. It is planned to extend the work to other minerals containing a smaller per cent of uranium and to introduce certain modifications in the method which will considerably increase its accuracy.

New Haven, Conn., June 29, 1904.

* Radio-activity, Cambridge University Press, 1904.

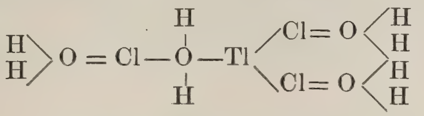
Art. XV.—*The Constitution of Hydrous Thallic Chloride*; by F. M. McClenahan.

[Contributions from the Kent Chemical Laboratory of Yale University—CXIX.]

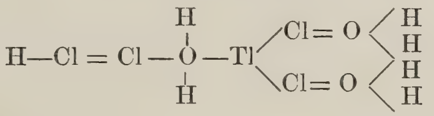
The nature of hydration and the constitution of the hydrous thallic chlorides have recently been the subject of discussion by Cushman* and R. J. Meyer.† The tetrahydrated thallic chloride $TlCl_3 \cdot 4H_2O$ is easily prepared, and Werther‡, and R. J. Meyer record the preparation of the monohydrate $TlCl_3 \cdot H_2O$, though Cushman was unable to actually isolate this salt. All assert that dehydration cannot be carried beyond the condition of the monohydrate without loss of chlorine. More recently Thomas§ has made record of the complete dehydration of thallic chloride without loss of chlorine by exposure for seventeen weeks over sodium hydroxide *in vacuo*, and ventures the opinion that there is little ground for believing that the relation of one of the molecules of water to the salt is different from that of the others. Meyer maintains that one of the chlorine atoms is not precipitated by silver nitrate and that it sustains a relationship to the complex different from the other two, so that the anhydrous salt may be represented by the symbol $(TlCl)\,Cl_2$. Cushman points out, however, that Meyer's use of Volhard's titrimetric method of analysis was faulty, inasmuch as the thallic salt acts as an oxidizer upon the standard potassium sulphocyanate employed to estimate the silver salt left over after precipitation of the chlorine by a standard solution of silver nitrate, and that in examinations of the filtrates from the usual gravimetric determination (by silver nitrate in presence of a sufficiency of nitric acid), no sign of incomplete precipitation of the chlorine was observed. Cushman concludes that the evidence which supports the writing of thallic chlorides as $(TlCl)\,Cl_2$, as well as all speculation from this point of view, falls to the ground. From experiments in which two specimens of a crystalline non-hygroscopic preparation of the tetrahydrated thallic chloride $TlCl_3 . 4H_2O$ were exposed twenty-one weeks in desiccators, the one over sulphuric acid and the other over phosphoric pentoxide, the conclusion was drawn by Cushman, that it may be taken as certain that the last fourth of the water comes off slowly

* Amer. Chem. Jour., 24, 222 (1900); 26, 505 (1901).
† Zeischer. Anorg. Chem., 32, 72 (1902).
‡ Jour. prakt. Chem., 91, 385 (1864).
§ Compt. Rend., cxxv, 1051 (1902).

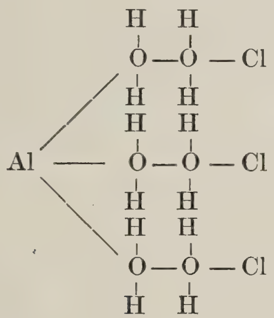
accompanied by chlorine, but that evidence for a definite monohydrate stage is slight. Cushman proposes to account for the relations of water of crystallization in salt complexes upon the hypothesis that oxygen can be quadrivalent and for the tetrahydrated thallic chloride suggests the symbol



and for the crystalline compound obtained by Meyer when the preparation of the hydrous thallic chloride is attempted in presence of hydrochloric acid the related symbol

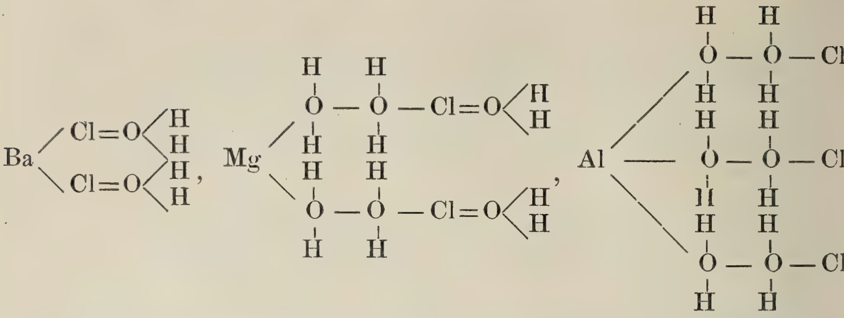


For the molecule of hydrous aluminium chloride Cushman suggests that the water is held within the complex in a manner suggested by the symbol



which brings out the observed fact that water cannot be broken from the molecule without formation of hydrogen chloride, at least in the primary action. The application of Cushman's hypothesis of the quadrivalent linking of oxygen in hydrous salts has been made in a former paper from this laboratory* to the comparative phenomena observed when certain typical hydrous salts, $BaCl_2 \cdot 2H_2O$, $MgCl_2 \cdot 6H_2O$, and $AlCl_3 \cdot 6H_2O$ are dehydrated in air and in an atmosphere of hydrogen chloride. It was shown that the phenomena of these salts are in harmony with the assumption of the symbols

* Gooch and McClenahan: this Journal, xvii, 365 (1904).



in which the molecules of water which may be expelled easily by heat without loss of hydrogen chloride, and at the same rate in air and in hydrogen chloride, are placed outside the chlorine of complex, while those molecules of water which are removed with more difficulty and at a rate affected by the environment, air or hydrogen chloride, are placed inside the chlorine. The suggestion was made that the influence of hydrogen chloride as compared with that of air upon molecules outside the complex is insignificant, while upon molecules of water within the complex the effect may appear variably, according to conditions, (1) in a retardation of dehydration and greater stability of the whole complex, or (2) in acceleration of dehydration with formation of the anhydrous chloride or with hydrolysis implying loss of hydrogen chloride and formation of a residual hydroxide or oxide.

In the present paper, the changes which the thallium chloride $TlCl_3 \cdot 4H_2O$ undergoes when heated in air and in hydrogen chloride have been studied and discussed in relation to the hypothesis of quadrivalent oxygen.

Experimental Part.

Thallous nitrate was dissolved in distilled water and the thallium precipitated as the chloride by means of hydrochloric acid. The precipitate was filtered on asbestos and washed thoroughly of all hydrochloric acid. It was then transferred to a test tube and chlorinated until the last traces of the solid were gone. The solution was evaporated to incipient crystallization and allowed to stand until the clear crystals of thallic chloride appeared. These were removed, dried by means of filter papers, desiccated for a brief period and a sample taken for analysis.

The chlorine in the salt was estimated by the usual silver chloride method, making sure of enough nitric acid. The thallium was estimated as thallous sulphate.* A weighed por-

* Browning: this Journal, ix, 137 (1900).

tion of the salt was transferred to a crucible and a few drops of sulphuric acid added. This was evaporated and the temperature was raised to approximately 200° C. The crucible was cooled in a desiccator and weighed, the weight of the residue was taken to be the acid thallous sulphate. The crucible was again heated and the temperature was raised to that of dull redness. After a suitable period of cooling it was again weighed, and the weight of the residue reckoned as the normal thallous sulphate.

Composition of the Salt.

PREPARATION I.

	Found.	Theory for $TlCl_3 \cdot 4H_2O$.
Thallium	53·74	53·36
Chlorine	27·81	27·80
Water (by difference)	18·45	18·84
	100·00	100·00

Weighed portions of this salt were transferred to weighed porcelain boats which were placed in combustion tubes passing through a water bath after the fashion of boiler tubes. A slow current of dry air was sent through the tubes kept at 100°. At the end of an hour the boat was removed and weighed. The residue in the boat was dissolved in water containing nitric acid and the chlorine estimated by precipitation and weighing as silver chloride. The calculated composition of the salt is given below.

Dehydration of $TlCl_3 \cdot 4H_2O$ at 100°, in one hour.

Weight of salt taken. grms.	Loss. grms.	Per cent. loss.	Chlorine in residue. grm.	Chlorine in residue.	Loss of Chlorine. Per cent.
0·1572	0·0282	17·94	0·0430	27·36	·45
0·1615	0·0298	18·45	0·0447	27·68	·13
0·2252	0·0402	17·85	0·0620	27·55	·26
0·2221	0·0396	17·83	0·0614	27·65	·16
0·1343	0·0237	17·65	0·0371	27·63	·18
0·1719	0·0308	17·92	0·0473	27·51	·30

Obviously the hydrolytic decomposition during the process of dehydration at 100° is very small in the case of the hydrous thallium chloride $TlCl_3 \cdot 4H_2O$. By the passage of dry air at 100° over the salt for an hour, nearly anhydrous thallic chloride was obtained, with small loss of chlorine, averaging about 1 per cent of the entire amount in the original salt. The anhydrous residue was crystalline and sparkling in the sunlight, but highly hygroscopic.

PREPARATION II.

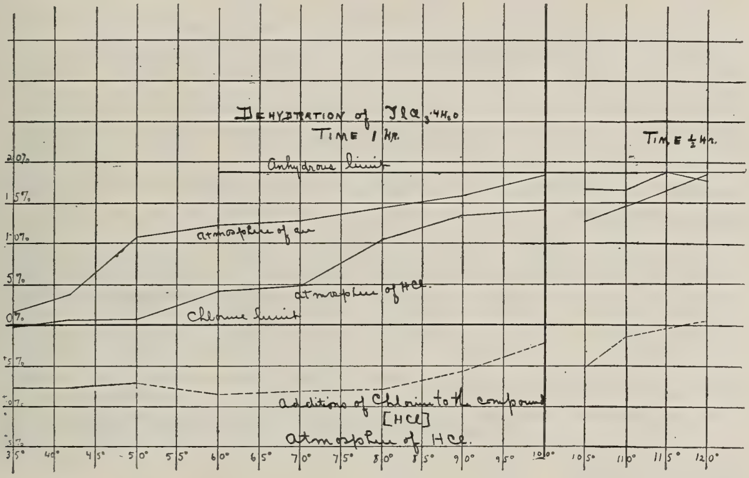
Number.	Weight heated.		Change of Weight when heated.				Chlorine in Residue.				Variation in Chlorine from theoretical constitution of salt.		Calculated gain or loss of HCl.		Loss of Water.		Temperature.
	In air. grm.	In HCl. grm.	In air. grm.	In HCl. grm.	In air. %	In HCl. %	In air. grm.	In HCl. grm.	In air. %	In HCl %	In air. %	In HCl. %	In air. %	In HCl. %	In air. %	In HCl. %	
1	0·1534	0·1777	−0·0025	+0·0148	− 1·63	+ 8·33	0·0421	0·0628	27·44	35·34	−0·36	+7·54	−0·35	+7·75	− 1·28	− 0·58	35°
2	0·1664	0·1889	−0·0065	+0·0135	− 3·91	+ 7·15	0·0466	0·0671	28·12	35·52	+0·32	+7·72	+0·33	+7·94	− 4·24	− 0·79	42°
3	0·1775	0·1825	−0·0190	+0·0118	−10·70	+ 6·40	0·0508	0·0637	28·62	34·90	+0·82	+7·10	+0·84	+7·30	−11·54	− 0·90	50°
4	0·1243	0·1416	−0·0153	+0·0063	−12·31	+ 4·45	0·0348	0·0514	28·00	36·29	+0·20	+8·49	+0·20	+8·73	−12·51	− 4·28	60°
5	0·2002	0·2086	−0·0253	+0·0065	−12·64	+ 3·12	0·0562	0·0730	28·07	35·00	+0·27	+7·20	+0·28	+7·43	−12·92	− 4·31	70°
6	0·1354	0·1290	−0·0194	−0·0034	−14·33	− 2·64	0·0378	0·0461	27·92	35·74	+0·12	+7·94	+0·12	+8·17	−14·45	−10·81	80°
7	0·1543	0·1594	−0·0245	−0·0122	−15·88	− 7·65	0·0433	0·0533	28·06	33·44	+0·26	+5·64	+0·27	+5·86	−16·15	−13·45	90°
8	0·1537	0·1617	−0·0284	−0·0195	−18·48	−12·06	0·0430	0·0482	27·98	29·81	+ ·18	+2·01	+0·18	+2·07	−18·66	−14·13	100°

PREPARATION III.

Number.	Weight heated.		Change of Weight when heated.				Chlorine in Residue.				Variation in Chlorine from theoretical constitution of salt.		Calculated gain or loss of HCl.		Loss of Water.		Temperature.
	In air. grm.	In HCl. grm.	In air. grm.	In HCl. grm.	In air. %	In HCl. %	In air. grm.	In HCl. grm.	In air. %	In HCl %	In air. %	In HCl. %	In air. %	In HCl. %	In air. %	In HCl. %	
9	0·1683	0·1472	−0·0284	−0·0112	−16·88	− 7·61	0·0477	0·0485	28·34	32·95	+0·54	+5·15	+0·55	+5·29	−17·43	−12·90	105°
10	0·1800	0·1442	−0·0300	−0·0189	−16·66	−13·11	0·0503	0·0423	27·94	29·33	+0·14	+1·53	+0·14	+1·57	−16·80	−14·68	110°
11	0·1384	0·1060	−0·0260	−0·0169	−18·79	−15·94	0·0380	0·0300	27·46	28·30	−0·34	+0·50	−0·35	+0·51	−18·44	−16·45	115°
12	0·1157	0·1426	−0·0202	−0·0263	−17·46	−18·44	0·0318	0·0385	27·59	27·00	−0·21	−0·80	− ·21	−0·82	−17·25	−17·62	120°

In the series of experiments next recorded, another preparation of the hydrous thallic chloride was dehydrated at various fixed temperatures in air or in hydrogen chloride, the loss of weight after a definite interval was noted, and the chlorine determined gravimetrically in the residues. The details of the experiments are given in the following statement. The course of dehydration in air and in hydrogen chloride and the action of hydrogen chloride upon the salt are represented in the diagram.

It is to be noted in the first place that although the preliminary analysis indicated a composition of the preparation of the hydrated thallic chloride used in these experiments, the close correspondence with the symbol $TlCl_3{\cdot}4H_2O$, there is an apparent slight gain in the chlorine contents of the chloride



when heated in air nearly throughout the series. This is probably due to an incipient dehydration of the salt before it was weighed out for the work, and the slight deficiency in the total amount of water generally found points in the same direction. Inasmuch, however, as it is a comparison of the behavior of the salt in air with its behavior in an atmosphere of hydrogen chloride which is to be studied, this trifling variation from normal constitution is not important.

It is manifest that the hydrous chloride takes on hydrogen chloride in some degree in an atmosphere of that gas at all experimental temperatures below 100°, and this is without doubt due to the tendency of the salt to form under the conditions of the chlorthallic acid observed by Meyer. At temperatures below 50°, the loss of water in an atmosphere of hydrogen

chloride is small, while the addition of hydrogen chloride is relatively considerable. For this range of temperature in an atmosphere of hydrogen chloride, the constitution of the salt corresponds to the symbol of the chlorthallic acid, $TlCl_3 \cdot 3H_2O \cdot HCl$, with some of the liberated water retained by the hygroscopic compound. At 60° and 70° this hygroscopic water volatilizes and the substance has, approximately, the composition represented by the symbol $TlCl_3 \cdot 3H_2O \cdot HCl$; at 80° the composition suggests the formation of some $TlCl_3 \cdot H_2O \cdot HCl$; while at 90° hydrogen chloride with more water is leaving the salt, and at 100° after an hour's heating, and at 110° after a half hour, the composition corresponds to a mixture of salts, $TlCl_3 \cdot H_2O \cdot HCl$ and perhaps some $TlCl_3 \cdot 3H_2O \cdot HCl$ with $TlCl_3 \cdot H_2O$. At 115° after a half hour the hydrogen chloride is nearly gone and the further dehydration of $TlCl_3 \cdot H_2O$ has begun; and at 120° the product is practically the anhydrous salt, $TlCl_3$, slightly reduced to the thallous-thallic chloride. When a comparison is instituted between the results obtained by heating the salt in air to temperatures above 100°, where the chlorthallic acid is breaking down, and those obtained under similar conditions of temperature in hydrogen chloride, it is obvious that dehydration of the salt $TlCl_3 \cdot H_2O$ is inhibited by an environment of hydrogen chloride.

Reverting now to Cushman's diagram* of the results obtained by long exposure of the hydrated thallic chloride, $TlCl_3 \cdot 4H_2O$, in desiccators at the ordinary temperature, it appears that two molecules of water disappeared from the salt in the course of a week, that the third molecule required for its removal five weeks, and that the fourth molecule vanished only after fifteen weeks more. The general order of the phenomena is in accord with the observations recorded above for the behavior of the salt at higher temperatures during the interval of an hour.

As appears from Cushman's diagram, the preparation of the dehydrated chloride, $TlCl_3 \cdot 2H_2O$, should be very easy. This salt was therefore made the starting point of a series of experiments upon the rate of dehydration in air. A new sample of the chloride, $TlCl_3 \cdot 4H_2O$, was crystallized out and this was desiccated over calcium chloride for three days, until upon analysis the residue was found to have the constitution shown by the symbol $TlCl_3 \cdot 2H_2O$. In this analysis the chlorine was determined, as usual, in the form of silver chloride, precipitated in presence of a sufficiency of nitric acid, and the thallium was estimated as the light yellow thallium chlorplatinate precipitated by chlorplatinic acid from the solution of the thallous salt reduced by sulphur dioxide and weighed on asbestos.

* Loc. cit.

Composition of the Salt.

	Found. I.	Found. II.	Mean.	Theory for $TlCl_3 \cdot 2H_2O$.
Thallium	59·18	59·24	59·21	58·91
Chlorine	30·77	30·72	30·74	30·70
Water (by difference)			10·05	10·39
			100·00	100·00

Portions of this salt were submitted to dehydration in air in the manner previously described, the boats holding the substance being heated in the tube-bath, generally for intervals of fifteen minutes, and then cooled in a desiccator and weighed. The data of these experiments are shown in the following table and diagram:

Dehydration of $TlCl_3 \cdot 2H_2O$, in Air.

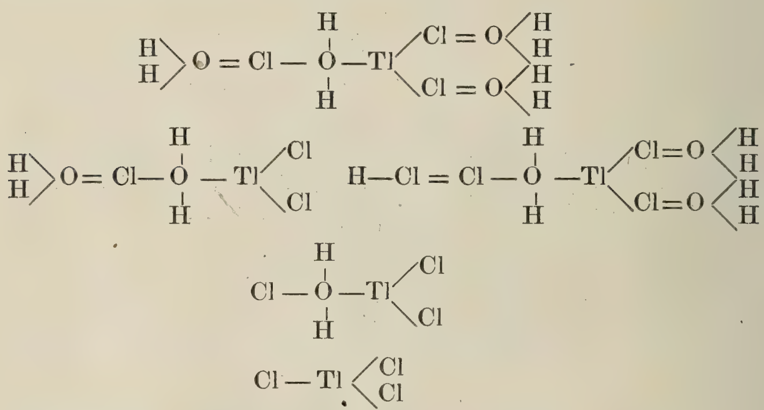
Weight taken. grm.	Loss of Weight. ¼ hr.	¼ hr.	¼ hr.	¼ hr.	¼ hr.	¼ hr.	¼ hr.	¼ hr.	½ hr.	2 hrs.	Chlorine loss. %	Water loss. %
0·2471 grm.	0·0097	0·0134	0·0160	0·0197	0·0221	0·0243	0·0250	0·0255	0·0269	0·0273	----	--
Per cent.	3·92	5·42	6·48	8·00	8·94	9·88	10·12	10·32	10·89	11·05	0·51	10·54
0·3441 grm.	0·0191	0·0248	0·0266	0·0276	0·0308	0·0345	0·0358	0·0371	0·0382	0·0390	----	--
Per cent.	5·55	7·21	7·73	8·02	8·95	10·03	10·40	10·78	11·10	11·33	0·54	10·75
0·3083 grm.	0·0209	0·0241	0·0263	0·0283	0·0302	0·0335	----	----	----	----	----	---
Per cent.	6·78	7·82	8·53	9·18	9·80	10·87	----	----	----	----	0·50	10·37
0·3081 grm.	0·0168	0·0221	0·0237	0·0256	0·0281	0·0306	0·0324	----	----	----	----	----
Per cent.	5·45	7·17	7·69	8·31	9·12	9·93	10·52	----	----	----	0·61	9·91
0·2500 grm.	0·0197	0·0217	0·0235	0·0254	0·0264	0·0279	----	----	----	----	----	----
Per cent.	7·88	8·68	9·40	10·16	10·56	11·16	----	----	----	----	0·45	10·71
0·2250 grm.	0·0177	0·0192	0·0203	0·0221	0·0228	0·0235	----	----	----	----	----	----
Per cent.	7·87	8·53	9·02	9·82	10·13	10·45	----	----	----	----	0·51	9·94

The residues remaining after heating were treated with water, the small amounts of thallo-thallic chloride found in every case and indicating the slight decomposition of the thallic chloride were dissolved by nitric acid, and the combined chlorine was precipitated as silver chloride. The difference between the chlorine thus found and the chlorine of the original salt is tabulated as "chlorine lost" in the process of dehydration. The loss of water was computed as the difference between the total loss observed and the hydrogen chloride corresponding to the chlorine lost. From these results it is obvious that the salt of constitution corresponding to the symbol $TlCl_3 \cdot 2H_2O$ loses the first molecule of water (5·2%) with comparative ease, while the second molecule disappears gradually on prolonged heating.

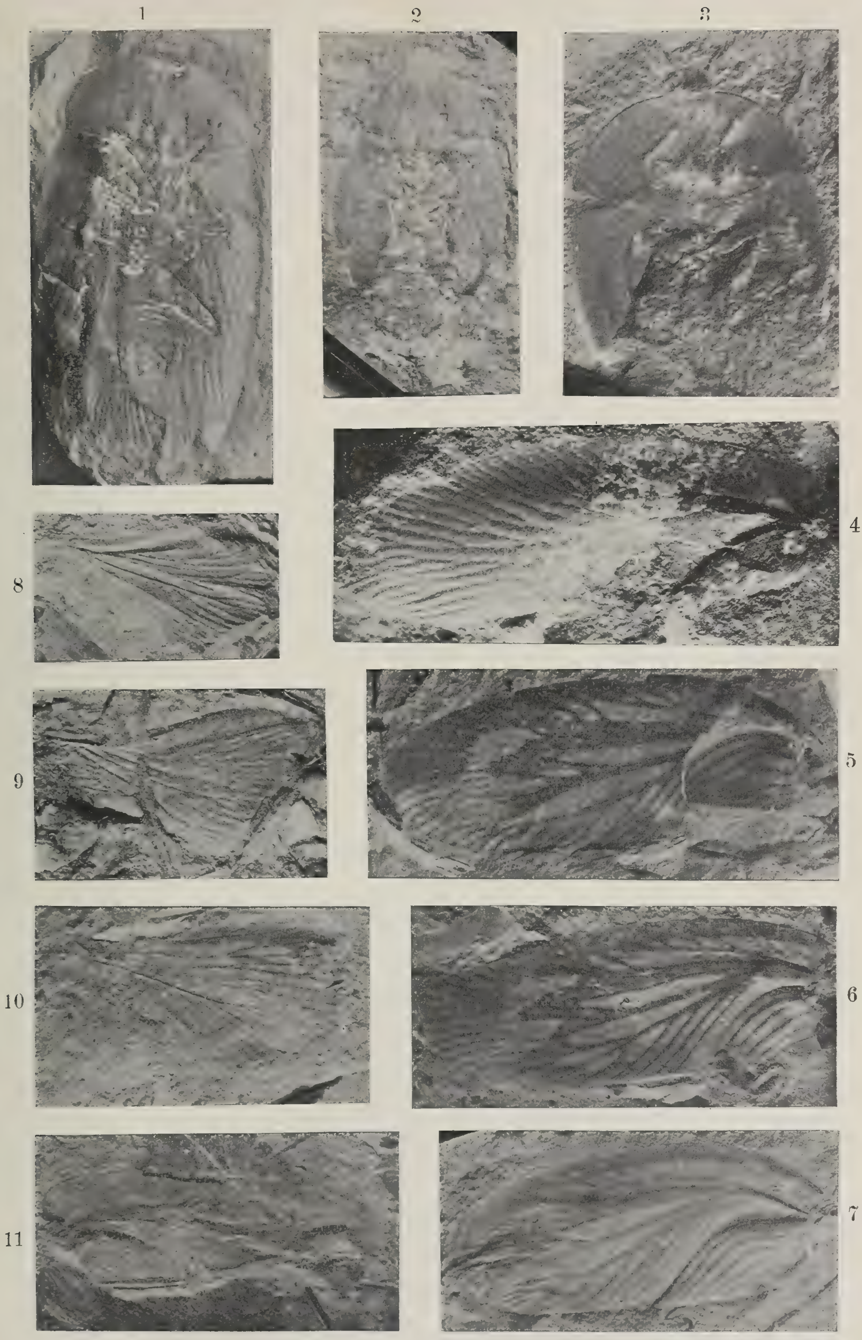
Taking into consideration all the observed phenomena which have been described, it appears that the water in the hydrous thallic chloride $TlCl_3 \cdot 4H_2O$ is held in the complex in three different ways, and that the relation may be reasonably expressed by the symbol $TlCl_3 \cdot H_2O \cdot H_2O \cdot 2H_2O$, the fourth molecule of water being removed less easily in an atmosphere of hydrogen chloride than in air. We have, therefore, the sequence of changes during dehydration represented by the following symbols:

In air.	In HCl.
$TlCl_3 \cdot H_2O \cdot H_2O \cdot 2H_2O$	$TlCl_3 \cdot H_2O \cdot H_2O \cdot 2H_2O$
$TlCl_3 \cdot H_2O \cdot H_2O$	$TlCl_3 \cdot H_2O \cdot HCl \cdot 2H_2O$
$TlCl_3 \cdot H_2O$	$TlCl_3 \cdot H_2O$
$TlCl_3 \cdot$	$TlCl_3$.

These symbols and the phenomena which they cover may be represented upon the hypothesis of quadrivalent oxygen by Cushman's symbol and its derivatives.



The author wishes to express his appreciation of the kind advice of Prof. F. A. Gooch in the preparation of this paper.



Paleozoic Cockroaches.

Art. XVI.—*A Study of the Structure of Paleozoic Cockroaches, with Descriptions of New Forms from the Coal Measures;** by E. H. Sellards. (With Plate I and thirty-seven figures in the text.)

Contents.

Introduction.

The well-known habits of many species of cockroaches, their abundance, and comparatively generalized structure have made them familiar insects and favorite objects of study. They are a characteristic and easily recognized group, separated from all other insects by a number of important structural differences. The body is flat and carried close to the ground. Progression is by a rapid scurrying motion. The tergum of the first thoracic segment, or pronotum, is large, broad, and typically more or less shield-shaped, forming a shelter under which the small flat head can be more or less completely withdrawn. The anal area of the front wing is distinctly marked off by a strong furrow. In recent species the abdomen of the female has undergone considerable modi-

* A paper prepared in the laboratory of paleontology, Yale University Museum, and constituting part of a thesis presented in May, 1903, to the faculty of the Graduate School of Yale University for the Degree of Doctor of Philosophy. As published here, it has been found necessary to omit from the systematic part of the paper, as originally prepared, descriptions of some of the new species, with the expectation that later these will be described elsewhere. The structural and general part of the paper, however, remains unchanged, except for the addition of the brief discussion of the classification of Paleozoic cockroaches, and a life-size restoration of the large cockroach *Archoblattina Beecheri* Sellards.

fication as a result of a specialized arrangement of the reproductive parts. A double fold in the ventral integument forms a characteristic genital pouch, bounded in front and above by the eighth and ninth and perhaps a vestige of the tenth sterna, and below by the enlarged seventh. The main function of this pouch is to retain the egg case while the eggs are being placed in it, and in some species during the period of incubation. The ovipositors have become very much reduced and adapted to serve the specialized function of guiding the eggs into the egg case. The terga of both male and female have also become more or less reduced. As will be seen from the present study, the abdomen and ovipositor, as well as the front and hind wings of the paleozoic cockroaches, are in important respects more generalized than in their living descendants.

Historical Résumé.—The cockroaches of the paleozoic have been known heretofore for the most part from the wings only. Being farther removed from the organic juices of the decaying body, the wings stand a better chance of preservation, especially the more or less coriaceous and resistant tegmina. The body, on account of the large amount of organic matter present, decays more rapidly, and no doubt often served as food for the numerous animals inhabiting the water at that time; hence is much more rarely preserved. The chitinous nature of the wings, on the contrary, renders them comparatively resistant. Moreover, as suggested in an earlier paper, it is probable that some of the small batrachians, dragon flies, or spiders, found in the same deposits, may have acquired the habit of biting off and rejecting the wings, as do the recent dragon flies, bats, and some arachnids. The detached wings are, moreover, readily carried by currents of water into places where permanent deposits are accumulating. The distinction between the paleozoic and recent forms was originally based almost entirely on differences in the front wings.* Some additional knowledge of the structure of other parts of the body has since accumulated from the studies of a considerable number of investigators, among whom are Scudder, Brongniart, Woodward, Deichmüller, Goldenberg, Geinitz, Germar, and others. After the tegmina, the pronotum is the part of the body most commonly preserved, and has been described in connection with the wings by several authors, especially by Scudder and by Brongniart. The habit of concealing the head beneath the pronotum was evidently already developed in paleozoic time, and it is usually rare that any portion of the head is apparent. Woodward detected parts of the head on *Etoblattina Peachii* and *Leptoblattina exilis*, on both of which

*Scudder, Mem. Boston Soc. Nat. Hist., vol. iii, p. 29, 1879.

the top of the head and the line dividing the epicranium may be seen.* But previous to the present study, the eyes and antennæ had not been observed. Surprisingly few hind wings have been described. Brongniart has figured some good ones without description.† Goeppert in his Fossile Flora der permischen Formation, Plate 28, figures under the specific name *Blattina neuropteroides*, what is evidently a small hind wing. In Bulletin 124 of the U. S. Geological Survey, Scudder has described several additional hind wings and reviewed those that had come to his notice up to that time. The legs, with the exception of the tarsus and basal elements, have previously been described in a general way. Deichmüller's *Etoblattina flabellata*, var. *Stelzneri*, preserves on the type specimen the outlines of the coxæ, trochanters, femora, and tibiæ.‡ The *Anthracoblattina sopita* Scudder (*Blattina didyma* Geinitz) shows the femur and tibia of the second pair of legs and the femur, tibia, and a part of the tarsus of the third pair.§ Indications of legs have been noticed by various authors on a number of specimens.

The sword-shaped ovipositor first noticed by Brongniart‖ is one of the most striking differences between paleozoic and recent cockroaches. The presence of the ovipositor can now be verified from American material, and its structure more fully described. Woodward had previously recognized the presence of cerci on these fossils and distinguished the ten abdominal terga, observing that the eighth and ninth were not reduced as in the living forms. The writer in a short paper appearing in the April, 1903, issue of this Journal, gave some additional structural characters of paleozoic cockroaches. Mr. A. L. Melander in the February-March number of the Journal of Geology, 1903, published, however, during the month of April, figures an additional cockroach from Mazon Creek.

Localities and Collections.—Almost all the American material preserving the structure of the body has come either from the Middle or Lower Coal Measures at Mazon Creek, Illinois, or from the Upper Coal Measures at Lawrence, Kansas. In the spring of 1901, the writer discovered the presence of fossil insects among plants collected by Mr. Martin and himself, from the Haverkampf farm near Lawrence.¶ Subsequent

* Geological Magazine, Decade 3, vol. iv, p. 49, 1887; ibid., p. 433.

† Histoire des Insectes Fossiles, atlas, pl. 47, 1893.

‡ Sitzungsb. Gesellsch. Isis, vol. xxxiv, p. 34, 1882.

§ Geinitz, Neues Jahrb. für Min., pp. 4–5, 1875.

‖ Comptes Rendus, Feb. 4, 1889, p. 252; Hist. des Ins. Foss., p. 417, 1894.

¶ A single specimen from a nearby locality in the same formation, found many years earlier by Mr. Joseph Savage, was sent to Lacoe and subsequently described by Scudder as *Etoblattina occidentalis* (Mem. Boston Soc. Nat. Hist., vol. iv, No. 9, p. 410, pl. 32, fig. 4, 1890).

visits to the locality resulted in the discovery of as many as fifty specimens, indicating the comparative abundance of the insects. Later in the summer the Kansas Geological Survey sent a party into the field and obtained in all over two hundred specimens, among them a considerable number of immature forms, or nymphs, or more properly in most cases the sheddings or moults of nymphs. In the fall of the same year, Professor C. E. Beecher very generously placed at the writer's disposal for study the Yale collection of paleozoic cockroaches, especially rich both in nymphs and in adults preserving structural characters. During the past two summers the writer has almost doubled the original number of specimens from the Lawrence Shales, the later collections containing especially instructive nymphs. More recently, Mr. Charles Schuchert has very kindly sent for comparison and study the cockroaches from Mazon Creek contained in the Lacoe collection of the United States National Museum. Mr. L. E. Daniels, through Mr. Schuchert, has loaned from his private collection several specimens from the Mazon Creek locality. During the summers of 1902 and 1903 the writer also obtained a collection of over two thousand fossil insects from a new locality in the Permian of Kansas. Cockroaches in the Kansas Permian are very much in the minority as compared with other families. A considerable number, however, were secured, and these, although not described in detail, have been useful in comparing with those from lower horizons.

Acknowledgments.—The results of an investigation of this kind depend to a considerable extent upon the success of developing and cleaning the fossils. This is especially true of the Mazon Creek specimens, in which the contrast between fossil and matrix is often slight, and the indurated nodules are difficult to work. It was the writer's good fortune in this study to have the advantage of the direction and guidance of the late Professor C. E. Beecher, whose skill in preparing and wide experience with fossils made his suggestions of inestimable value. Moreover, not a little of the skill and ingenuity for which this master of paleontological technique was famous had been expended, with the usual excellent results, on several of the Mazon Creek specimens of the Yale Museum before the collection came into the writer's hands for study. It is also a pleasure to acknowledge indebtedness to Dr. S. W. Williston, Mr. Charles Schuchert and Mr. L. E. Daniels. Dr. Williston encouraged the development of the Lawrence locality, and made the collections belonging to the University of Kansas accessible for study. Mr. Schuchert has contributed not a

little by supplying important types from the National Museum collection. The specimens sent by Mr. Daniels have been of the greatest interest, as adding to the collections from the famous Mazon Creek locality.

Nomenclature used in dealing with the Nymphs.—In attempting the study of a collection of fossil cockroaches, including numerous specimens in the nymph stages, the investigator is met at the outset by the perplexing question of nomenclature. It will rarely be found possible to identify all the nymphs with their respective adult species. When only a few nymphs are to be dealt with, no great inconvenience results from simply referring them to their tribe, or genus, if possible, as immature forms. But when, as in the present instance, a large number are at hand which separate themselves naturally into specific groups, some means of designating a group as a whole becomes practically necessary. Accordingly, in a few instances specific names have been retained or proposed for well-defined species as a means of reference until their connection with adults can be established. Inasmuch as it is difficult, if not impossible, to distinguish the closely related genera of the tribe Mylacridæ in the nymph condition, it has been thought admissible to use the type genus *Mylacris* in a somewhat extended sense, to include the nymphs of the tribe. *Etoblattina* is used in the same way to some extent for the Blattinariæ, although this tribe is more varied, and generic characters seem to appear earlier.

Terminology of the Veins of the Wing.—The system of designating the veins used in the description of species in the present paper is that developed by Redtenbacher and now fortunately coming into general use in entomology. This recognizes in the typical wing five main veins, aside from those of the anal area. It is much to the credit of this system that it is readily applicable to the wings of the simple and comparatively unspecialized insects of the paleozoic. A great deal has been done in recent years to establish the essential unity of the plan of structure of the wing and to discover the homologies of the main veins in the different orders of insects, with the result that many entomologists are now convinced that all winged insects have descended from a common winged ancestor. The complicated arrangement of the veins, so difficult to decipher in the wings of many living adult insects, becomes more and more simple as the phylum is traced toward its point of origin. As paleontological evidence becomes more complete, the steps in the differentiation of the wing can be more closely followed. Inasmuch as the terminology of the veins and their

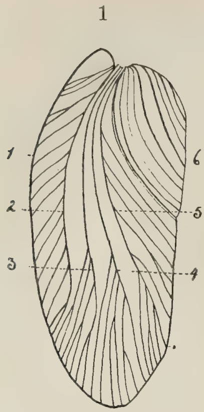


FIGURE 1. — *Gerablattina arcuata* Sellards.

areas used in this paper is different from that proposed by Heer and employed heretofore in the literature of American paleozoic insects, it has been thought advisable to introduce a sketch of the wing of a typical member of the Paleoblattidæ, giving Redtenbacher's and Heer's names in parallel columns.

Terminology of the wing veins as developed by Redtenbacher.	Terminology of the wing veins applied by Heer to cockroaches.
1. Costa.	Marginal.
2. Subcosta.	Mediastinal.
3. Radius.	Scapular.
4. Media.	Externomedian.
5. Cubitus.	Internomedian.
6. Anal veins.	Anal veins.

Structure of Paleozoic Cockroaches.

Head.—The head is small, flattened, and capable of being withdrawn partly or entirely beneath the pronotum. The part most commonly seen is the top, or top and front. The sutures dividing the parts of the head are often discernible. The eyes are placed well up toward the top. Their shape is obscured by crushing, but they were large and apparently elongate or reniform. The frons or clypeus posterior is occasionally recognizable (Text-figure 9). The mandibles have not been observed. Supposing them to have been as firmly chitinized as at present, their absence where more delicate structures are preserved is unexpected, and suggests the possibility that the early cockroaches may have fed on soft vegetation, and have had less strongly chitinized mandibles than their omnivorous descendants. The antennæ are long, slender, and many jointed. They are enlarged at the base and united to the head by a circular socket-like attachment (Text-figures 4 and 19).

Thorax.—The segments of the thorax, as in living generalized insects, are not fused or closely united. The pronotum presents considerable variation in shape in the different genera and species, and goes through a regular series of changes during the growth of the individual. At first the posterior border is straight, the lateral angles pointed, and in the Mylacridæ directed backward. As growth progresses the corners become less acutely pointed, then rounded, and the posterior border fuller. The pronotum of the adults of the tribe Mylacridæ is always proportionately broad, but with a rounded posterior border. Among the Blattinariæ the modification progresses

farther, many of the adults of this tribe having an almost circular pronotum. In describing *Etoblattina Peachii* Woodward (*loc. cit.*) refers to a prominent notch in the pronotum. From the illustration given it would seem that the notch was not natural, but caused by the decay and more rapid erosion of the pronotum directly over the head, a feature not uncommon in similar iron-stone nodules from Mazon Creek (Text-figure 7).

Front Wings.—The front wings have been thoroughly studied by Scudder and others, and their distinctive and primitive characters pointed out. The four principal veins of the front wings,—subcosta, radius, media, and cubitus, are distinct to the base. In most living forms two or more of the main trunks disappear by fusion with the adjoining veins, although all four can be seen in their original position in the living nymphs (Text-figure 37). The anal area was well marked off as early at least as the middle of the Carboniferous, but the anal veins, as Goldenberg and Scudder have noted, end with rare exception on the inner border, while, as a rule, among living forms the anal veins end on the furrow. The tegmina were for the most part less coriaceous than those of living forms. Well-developed cross veins are comparatively rare.

Hind Wings.—The hind wings are thinner and more delicate than the front and are much less often preserved. They do not fold longitudinally as do the hind wings of living cockroaches. Cross veins as far as known are absent. The anal area did not present so great a spread as that of modern cockroaches, and, as Scudder has said, does not seem to have been plaited as in almost all modern forms. The costa is submarginal and occasionally gives off one or two superior branches. The veins of this wing are more uniformly developed than in the hind wings of most modern cockroaches. Strength is obtained as in living forms by a subcostal fold. The costal border is nearly straight or a little concave near the base. The inner border is full and well rounded, making the wing broad in proportion to its length (Text-figures 33–36, and Figures 8–10 of Plate I).

Legs.—The legs are not uncommonly preserved, showing either as impressions through the integument or projecting from beneath the body. The second pair is somewhat larger than the first, and the third longer than the second, indicating that progression was by running. The tibia, of some forms at least, was spinous (Text-figures 8 and 14). The femur, on the contrary, was probably smooth, since well-preserved femora show no indications of spines. The first joint of the tarsus seems to have been comparatively long. The number of segments is not distinct on any specimen at hand, but the tarsus was terminated by a claw (Text-figure 23).

Abdomen.—Ten terga are to be seen on the abdomen of both male and female. The projecting edges of the terga are well developed from the third or fourth to the ninth. The tenth tergum is smaller and more or less rounded. The two cerci project from beneath it. The seventh, eighth, and ninth terga are well developed, presenting in this respect a marked contrast to the common existing cockroaches, among which the corresponding terga in both male and female are very much reduced and partly covered by the seventh, even in the later nymph stages. More difficulty is encountered in the study of the sterna. They are seen either in outline through the terga, or, the terga having been removed, are viewed directly. The first sternum, which was doubtless, as in living forms, much reduced and imperfectly chitinized, has not been observed. The third to the ninth can be seen lying beneath their respective terga on a few individuals, presumably males. The seventh sternum of the female is enlarged, rounded, and lies beneath the seventh, eighth, and a part of the ninth terga. The relative position of the parts can be determined from several specimens (Figure 12). The position of the eighth and ninth sterna of the female has not been determined. As Brongniart has suggested (Hist. Ins. Foss., p. 417), the habit of depositing the eggs within an egg case was probably not common at that time. Many of the species doubtless deposited their eggs singly either on the ground or underneath the bark of trees or within small stems. Certain paleozoic ferns in immediate association with cockroaches have been observed to present a row of slits along the rachis, which appear to have been made by such an organ as the ovipositor of the Paleoblattidæ, and, as has been stated in an earlier paper, are indeed strikingly similar to scars seen on the stem of the common *Amorpha fruticosa* (false indigo) and said to be made by katydids.* Nevertheless some genera may have acquired the habit of putting the eggs within egg cases as early as the latter part of the Carboniferous. The writer has recently obtained a fossil from the Upper Coal Measures of Kansas which has a striking resemblance to the egg cases of modern cockroaches (Figure 25).

Ovipositor.—The ovipositor is present on several specimens. The parts of this organ in one very young individual of *Etoblattina mazona* (Figure 11) have apparently not yet united, and present a striking similarity to the early stages in the development of the ovipositor in the Locustidæ, as

* A description of the scars found on the rachis of *Tæniopteris* Brongniart and *Glenopteris* Sellards has been given by the writer in the Kansas Univ. Quart., vol. ix, p. 184, July, 1900; ibid., vol. x, pp. 9–12, Jan., 1901. Similar scars on *Tæniopteris* from West Virginia are described by Fontaine and I. C. White (Perm. Flora, p. 92); and on *Macrotæniopteris* from Virginia by Fontaine (Mon. VI, U. S. G. S., Older Mes. Flora, p. 18, 1883).

figured for *Locusta* by Dewitz.* From this specimen it appears that the ovipositor is composed of probably three pairs, of which the inner is the smallest. In the later stages when the three pairs have become united the component parts are indicated by a groove down the center (Figure 13).

Cerci.—The cerci, which are not uncommonly preserved, vary a good deal in length in the different genera and species, from very long as in *Etoblattina juvenis* to a moderate length as in *E. mazona* and other species. Usually the cerci are directed obliquely to the body; occasionally, however, they stand at right angles, as in *Mylacris anceps.*

Development.—The development, as shown by the numerous nymphs of the collections representing various stages in the ontogeny of single species, is, as in modern cockroaches and other Orthoptera, direct, the young resembling the adults and growth taking place by a succession of moults.

Classification and Description of Carboniferous Cockroaches.

Order *Orthoptera.*

The Carboniferous cockroaches are quite generally recognized as constituting a group of family rank, the Paleoblattidæ, in contradistinction to the modern family Blattidæ. In the disposition of the Paleoblattidæ under the larger divisions, there is, unfortunately, no such uniformity of usage. They are, by some, separated entirely from their modern descendants and included along with other insects in a distinct order, the Paleodictyoptera. By others they are referred directly to the Orthoptera. This diversity of classification, affecting all the paleozoic insects, results not so much, perhaps, from any disagreement as to the essential facts presented, so far, at least, as cockroaches are concerned, as from a difference in the viewpoint from which the facts are interpreted and applied.

The chief contention for the establishment of the order Paleodictyoptera, as expressed by Professor Samuel H. Scudder, is that paleozoic insects as a whole are more closely related among themselves than to their (known) descendants of mesozoic and later times,—a classification in which emphasis is given to the interrelation of contemporaneous but diverging groups, or the lateral relation of organisms, rather than to the lineal or phylogenetic relation in time of particular lines of development. The question of the classification of paleozoic insects in general is not within the range of this paper and will not be touched upon here, except in so far as the principles applied affect the disposition of the Orthoptera as represented by the cockroaches. The gap between the Carboniferous

* Zeit. für wiss. Zool., vol. 25, p. 176, pl. 12, figs. 1-11, 1875.

representatives of modern Orthoptera and the early forms of other orders is, even at that time, an actual one, indicating a considerable divergence in the phylogenetic lines. On the other hand, the apparent break between Carboniferous and later Orthoptera is accidental and due to the fact that not all of the intermediate forms have been preserved, or if preserved have not yet been found. The object of schemes of classification, as is universally conceded, is to express, as far as possible, phylogenetic relations. Following this leading principle, any natural group of organisms should be recognized as extending back in time until a point is reached at which that group coalesces with a group or groups of coördinate rank, or unites with the parent stock. It may often be a matter of difficulty, owing to the imperfect geological record and other causes, to determine the exact point of origin of a group from an ancestral stock. In the case of the Orthoptera, however, the evidence at hand seems conclusive that the order as a distinct phylum is recognizable well into or beyond the Carboniferous. Not only does the body structure of these early forms present the essential features of the Orthoptera, but the development, as is here shown, is in entire agreement with that of modern forms, the young resembling the adults and growth taking place by a succession of moults during which the wings appear gradually.

Super-Family *Blattacea.*

The cockroaches of the Carboniferous, as shown by the foregoing detailed account, are closely related to those of mesozoic and later times. The early forms present not a few generalized characters, such, for example, as the protruding ovipositor, lessening the interval separating them from other primitive Orthoptera. Nevertheless they have already acquired many of those peculiarities which distinguish them from all other insects, notably the rounded shield-shaped pronotum, the small, flat, retractile head, the characteristic strongly delimited anal area of the front wing, the flat bodies, and, without doubt, the peculiar scurrying motion. The indications are that their habitat was much the same. Their constant association with fossil plants, especially ferns, suggests that they were then, as now, fond of moist low places, with abundant vegetation, along the banks of rivers and marshes. Such differences as are found are those resulting naturally from development and specialization, as increased differentiation between the front and hind wing, greater complexity of the wing venation, and the reduction of the ovipositor by specialization. The indications are that the line representing the cockroaches diverges from that of other insects during the early Carboniferous or pos-

sibly before, and is from that time on a distinct and continuous line. The customary separation of the group into an older and a newer part,—the Paleoblattidæ and the Blattidæ, while in a sense artificial, is nevertheless convenient as marking two fairly distinct stages in the development of the phylum. The two families are best included within a single super-family characterized as follows, and for which the term Blattacea is here suggested:

Running Orthoptera; body flat and carried close to the ground; tergum of the first thoracic segment (pronotum) large, broad, typically shield-shaped; head small, flat, inflexed, capable of being more or less completely withdrawn beneath the pronotum; wings differentiated into a more or less thick front wing, and a thinner, broader hind wing; anal area of the front wing marked off by a strong furrow; hind wing not folded in the earlier forms, folded in the later; ovipositor projecting from the abdomen in the Paleoblattidæ, not, or but slightly, projecting in the Blattidæ.

The geological range of the Blattacea is from the Carboniferous to the present. Of the two families included, the Paleoblattidæ extend from middle or early Carboniferous to the close of the paleozoic, possibly lasting over into early mesozoic; the Blattidæ from late paleozoic or early mesozoic, to the present.

Paleoblattidæ.

Paleoblattariæ Scudder, Mem. Boston Soc. Nat. Hist., vol. iii, p. 26, 1879.
Paleoblattidæ Brongniart, Histoire des Insectes Fossiles, p. 416, 1894.

The Paleoblattidæ, the older and more primitive of the Blattacea, are characterized as follows:

Cockroaches with a well-developed and protruding ovipositor. Eggs probably deposited singly in the ground, in stems, or underneath the bark of trees. Hind wings not folded and consequently lacking differentiation into a brownish resistant, and a thin folded part. Anal area never plicated. Differentiation in texture and venation between the front and hind wings less marked than in the Blattidæ, the front wings being, as a rule, less coriaceous and the main veins in both wings more nearly equally developed. Cross veins, except for the reticulation of the membrane, are not common in the front wings, and are unknown in the hind ones.

Description of Genera and Species, including Nymphs.

Mylacridæ.

The Paleoblattidæ are again subdivided into two subordinate groups, the Mylacridæ* and the Blattinariæ. The former

* The term Mylacridæ in use for this group is misleading, since the termination is that accepted for family names. A better term is Mylacrinariæ to correspond with the coördinate division Blattinariæ.

present the more primitive structure and are not known later than the Coal Measures.

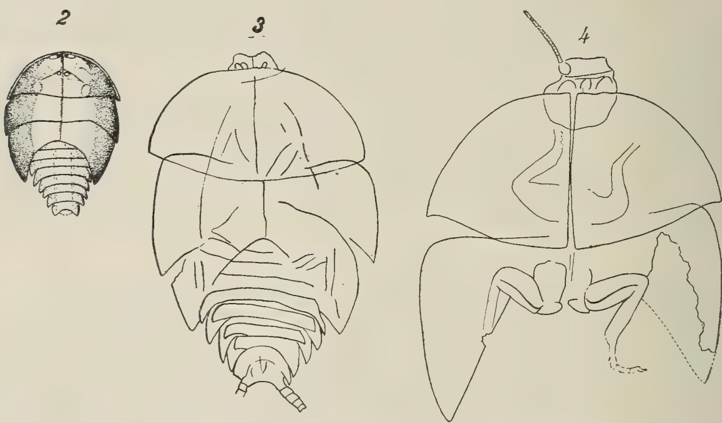
Mylacris.

Scudder, Geol. Surv. Illinois, vol. iii, p. 568, 1868; Mem. Boston Soc. Nat. Hist., vol. iii, pt. 1, p. 40, 1879.

Mylacris diplodiscus. Text-figures 2–4; Plate I, Figure 3.

Dipeltis diplodiscus Packard, Amer. Nat., vol. xix, p. 293, 1885; Mem. Nat. Acad. Sci., vol. iii, p. 145, 1886, pl. v, figs. 2 and 2[a]. Schuchert, Proc. U. S. Nat. Mus., vol. xix, p. 672, 1897, pl. lviii, figs. 2–5. Bernard, Natural Science, vol. xi, p. 397, December, 1897. Gahan, ibid., vol. xii, p. 42, January, 1898; Schuchert, ibid., p. 215, March, 1898. Scudder, in Zittel's Text-Book of Paleontology, Eastman's Translation, p. 687, 1900. Melander, Journal of Geology, vol. xi, p. 185, Feb.–March, 1903, pl. v, fig. 6; pl. vii, fig. 6.

Mylacris diplodiscus Sellards, this Journal, vol. xv, p. 309, April, 1903, pl. vii, fig. 8.



FIGURES 2–4.—*Mylacris* (*Dipeltis*) *diplodiscus*; all figures twice natural size. Figure 2, after Schuchert. Originals of Figures 2 and 4 in the National Museum; original of Figure 3 in the Yale University Museum.

This species is of much interest historically, having been the first nymph cockroach described from this country, although not recognized as such at the time.* No less than seven specimens of this species in different stages of development have now been obtained. The smallest individual observed, from the National Museum collection, figured by Schuchert (*loc. cit.*), and copied here (Figure 2), is hardly more than one centimeter in length. The pronotum is rounded in front and pointed at the lateral angles. The wing pads appear as lateral extensions of the thoracic terga, the two pairs being very similar in size, shape, and texture. The abdomen is small, short, and narrows

* For a history of *Dipeltis* and a redescription of the type specimen, the reader may consult the short paper by the writer referred to above.

rapidly from about the seventh to the tenth segment. The thorax is unusually large in proportion to the abdomen, being approximately twice as broad and twice as long as the abdomen. A later stage is represented by a specimen 14^{mm} long, and presents much the same proportions. The wing pads have become larger and the front pair now somewhat overlap the second pair. The specimen shown in Figure 3 has reached a length of 2^{cm}, exclusive of the head and cerci. The head as seen on this and other specimens is large; the eyes are here preserved as elongate ovate impressions. The largest specimens, which are presumably approaching maturity, are 3^{cm} in length. The pronotum in these later stages becomes slightly rounded at the lateral angles, the front wings are noticeably larger than the hind, and traces of the venation have appeared. The adult, when identified, will probably be found to have a broad pronotum rounded at the lateral corners, with wings longer than the short abdomen, and resembling in a general way the adults of *M. elongata*, which has, however, a proportionally longer thorax and a more strongly arched boxlike body. The most striking character of the species in its larval stages is the short abdomen and the large, broad thorax. The antennæ, cerci, sterna, and parts of the legs have been observed. The nymphs, not having been identified with the adults, may conveniently retain for the present the specific name already assigned to them. The reference of the species to the genus *Mylacris* is provisional, *Mylacris* being used, as explained above, in a general sense for nymphs of the *Mylacridæ*.*

Formation and Locality.—All the known specimens of this species are from the Coal Measures at Mazon Creek, Illinois.

Mylacris elongata. Text-figures 6–9; and Plate I, Figure 1.

Scudder, Bull. No. 124, U. S. Geol. Surv., p. 41, pl. i, fig. 6, 1895.

The thorax of the nymph referred to this species is large, the larger front wings overlapping the hind ones. The mould of the dorsal surface, from which Figure 6 is made, shows the ten segments of the abdomen. The first to the third terga are reduced. The abdomen is broadest at the fifth segment, and narrows to the tenth. The ninth and tenth terga of this species appear to be closely united, the last being small. A thickened line extends from the ninth across the tenth. The

* Mr. A. L. Melander, in a foot-note accompanying his reference cited in the synonymy above, suggests that the pronotum of this form agrees very well with that of *Promylacris rigida*. From a direct comparison of the types of the two species it seems probable that the pronotum of *Promylacris rigida*, which in the type specimen is distorted, and from which, moreover, the matrix has never been entirely removed, is proportionally less broad than that of *M. diplodiscus*.

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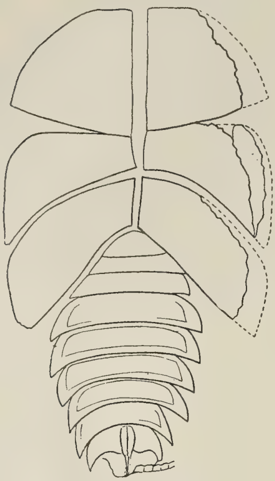

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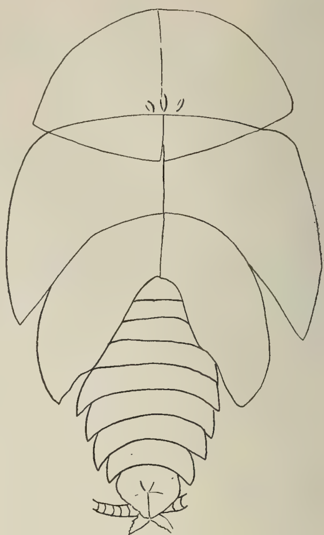

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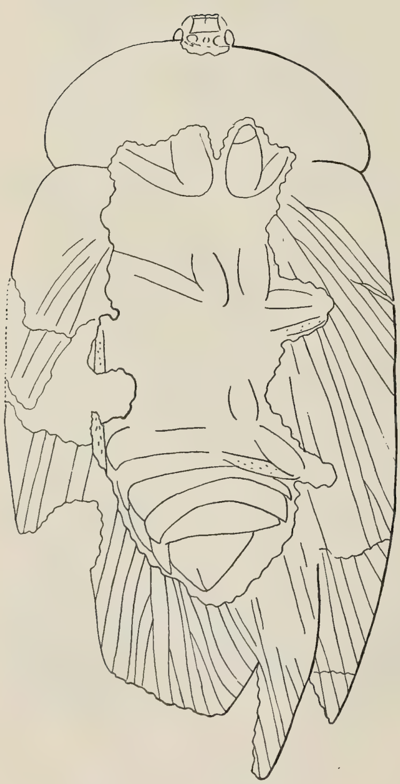

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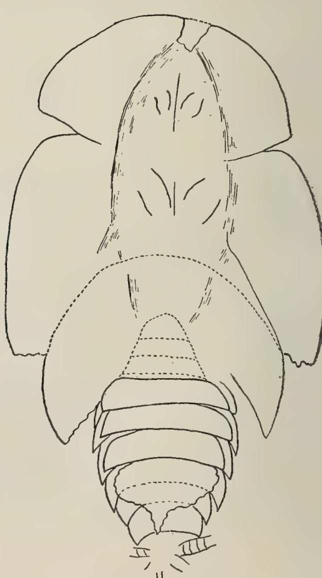


FIGURE 5.—*Mylacris anceps* sp. nov. Cast-off integument of nymph.

FIGURE 6.—Nymph of *Mylacris elongata* Scudder. The illustration is taken from the cast of the dorsal surface. The cerci of this species, as of *M. anceps*, stand at right angles to the axis of the body. The indistinct organ at the end of the abdomen may possibly be the crushed ovipositor.

FIGURE 7.—Same specimen; looking down upon dorsal surface. From this view a depression indicates the outline of the body. The notch in the front of the pronotum is due to erosion, the specimen having been exposed to weathering agents from 1871 to 1880 (see text, p. 119). The whole dorsal surface has suffered erosion during these nine years. Over the abdomen the terga have thus been partly removed, exposing the sterna.

FIGURE 8.—Adult *M. elongata.* The much crushed head is partly exposed. The pronotum, by the time the adult condition is reached, has become, as usual, much rounded at the corners. The dorsal surface has been partly removed to expose the legs and the abdominal sterna.

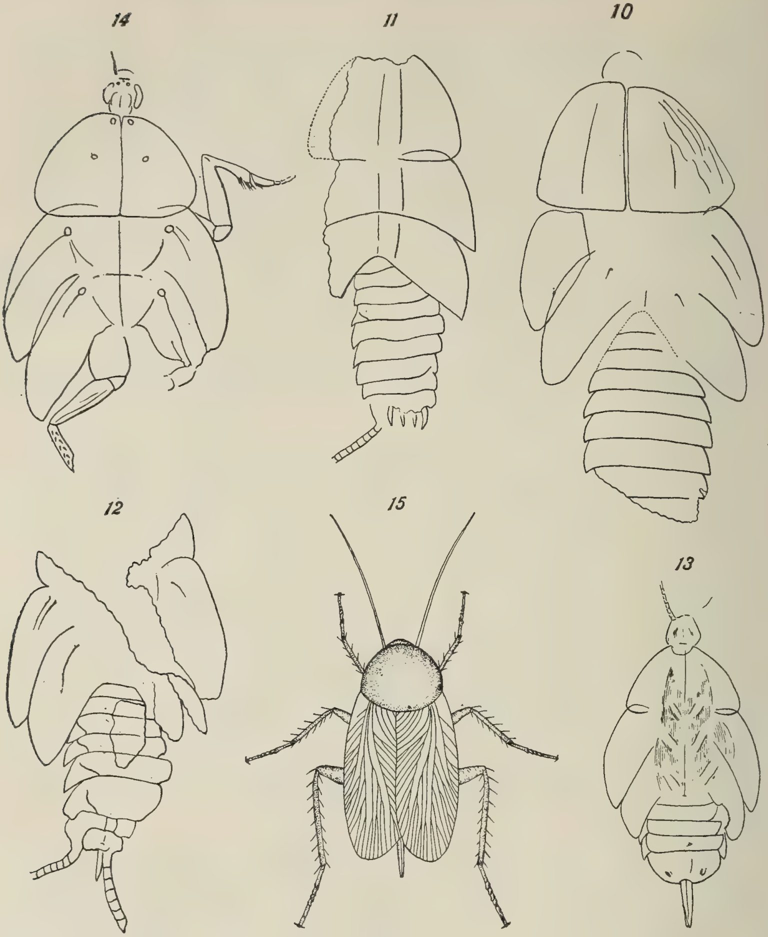
FIGURE 9.—Head of same specimen.

Figures 5–8 enlarged approximately two diameters; Figure 9, x4. All were obtained from the Coal Measures of Mazon Creek, Illinois. Originals in the Yale University Museum.

cerci are directed at right angles to the axis of the body and are comparatively strong, the joints near the base being twice as broad as long. The body of the insect (Figure 7) has suffered considerable erosion, as a result of which the terga of the abdomen have been removed, except at the edges, thus exposing the sterna. The more rapid erosion of the integument of the thorax over the head and legs reveals the location of these organs.* The sterna as seen in the illustration are of the normal Mylacrid type. The seventh is enlarged and rounded. A portion of some organ, probably the ovipositor, is seen on the inner side of the seventh sternum. At the end of the abdomen of both fossil and mould may be seen what appears to be the two parts of the ovipositor separated and spread open by crushing.

Two adults are referred to this species. The body of the adult exclusive of the head is 36^{mm} long. The abdomen is short as compared with the long thorax. The wings are large, the two pairs being of equal length and much longer than the abdomen. The body is arched transversely. The tegmina have a prominent humeral angle and fit down boxlike over the sides of the body. The pronotum is broad and rounded at the angles and has a full posterior border. The sterna of the specimen figured are visible. As in the nymph, the seventh sternum is enlarged and rounded, and has a depressed line which may represent the impression of the thickened ridge on the ninth tergum. The identification of the two adults with

* The history of the two parts of this specimen is of interest. The mould (Figure 6) was collected by Mr. S. S. Strong and sent to the Yale Museum in 1871 (lot No. 199). The opposite side of the nodule, evidently lost at the time, remained exposed until rediscovered by Mr. Strong and sent to the Yale collection in 1880 (lot No. 1400), having eroded during the intervening nine years to the extent mentioned in the text.



Etoblattina mazona Scudder.

FIGURE 10.—A nymph approaching maturity. The specimen has suffered lateral crushing, causing a wrinkling of the pronotum and giving the abdomen probably an unnatural width.

FIGURE 11.—A small nymph in which the parts of the ovipositor have not yet united. Two pairs are seen, the outer being larger and more curved, the inner smaller and straighter. Some other organs, probably a third pair of ovipositors, are indistinctly seen.

FIGURE 12.—A later stage in which the parts have become united and the ovipositor projects from the abdomen. The enlarged seventh sternum is here seen to lie underneath the eighth, ninth, and tenth terga.

FIGURE 13.—A nymph which, having the terga removed, exposes more of the ovipositor and sterna. The view obtained here as a result of the removal of the terga is of the upper (inner) side of the sterna. The ovipositor is seen to pass on the inner (upper) side of the seventh sternum. The impression of the dorsal surface of this specimen shows the ten terga and the cerci in position, confirming the relative position of the seventh sternum and the eighth, ninth, and tenth terga described for the specimen above (Figure 12).

FIGURE 14.—A nymph approaching maturity.
FIGURE 15.—Restoration of *Etoblattina mazona* Scudder, based upon the type specimen, the wings and pronotum of which are well preserved, and also upon the several nymphs now known preserving practically all parts of the body.
Figures 10–12, x3; Figure 15, natural size; all others, x2. All are from the Coal Measures of Mazon Creek, Illinois. Original of Figure 14 in the National Museum; all others in the Yale University Museum.

Scudder's species *Mylacris elongata* is based on the close agreement in the shape and venation of the tegmina. The connection between nymph and adult is inferred from the relative proportion in size between the thorax and abdomen, the large wings already evident in the nymph, and the similar boxlike shape of the body.

Formation and Locality.—Coal Measures, Mazon Creek, Illinois.

Mylacris anceps sp. nov. Text-figure 5.

The specific name *M. anceps* is proposed for the nymph illustrated in Figure 5, which can not at present be referred to its proper adult species. The most marked characters of the species are its long abdomen and short wings as compared with the species just described. The wings are unusually short considering the size of the nymph. The abdomen is almost or quite as long as the thorax, narrowly elliptical in outline, broadest at the fourth or fifth segment, sloping gradually to the tenth. The tenth tergum is small, and, as in the last species, apparently consolidated with the ninth, the union being strengthened by a strong ridge running down the center. The cerci in this species are also directed at right angles to the axis of the body. The adults will probably be found to have a proportionately broad and long abdomen.

Formation and Locality.—Coal Measures, Mazon Creek, Illinois. Type specimen in the Yale University Museum.

BLATTINARIÆ.

Etoblattina.

Scudder, Mem. Boston Soc. Nat. Hist., vol. iii, p. 56, 1879.

Etoblattina mazona. Text-figures 10–16; and Plate I, Figure 2.

Scudder, Proc. Boston Soc. Nat. Hist., vol. xxi, p. 391, 1882.

Etoblattina mazona is at present the most completely known paleozoic cockroach. A rather full description will therefore be given of several individuals representing stages in the development of the species. A restoration of the species as now known is also attempted. The smallest specimen seen is 15^{mm} long. The body is slender and the two wings appear as

triangular, pointed extensions of the meso- and meta-thoracic terga, equal in size and of a similar texture. The pronotum at this stage is abruptly truncated at its posterior margin. The abdomen is slender and long. The sterna of the specimen are partly exposed. The most remarkable feature in the fossil, giving it an especial interest, is the presence near the end of the abdomen of two pairs of organs and traces of a third, which appear to represent the parts of the ovipositor not yet united (Figure 11). These lie at a level below the edges of the terga and the cerci, but above that of the sterna. The stage of development of the ovipositor represented by this specimen is very similar to that of the young *Locusta* illustrated by Dewitz (*loc. cit.*). A later stage in the ontogeny of the species is represented by Figure 13. The wings are now directed obliquely backward, and are more arched. The dorsal integument of the abdomen is here entirely removed from the seventh sternum and ovipositor and from the rest of the abdomen except at the edges. The parts of the ovipositor have now become united, the line of union being indicated by a furrow. The ovipositor is seen to pass on the inner side of the large seventh sternum, and is incomplete, being broken at the tip. The part preserved is 3^{mm} long. The opposite side of the nodule shows the ten segments of the abdomen complete, together with the cerci. The sterna of the slightly larger individual shown in Figure 12 are also partly exposed. On the inner side of the seventh is what appears to be the ovipositor lying at a lower level and passing beneath the tenth tergum. The abdomen has suffered lateral crushing in fossilization so that the sterna are displaced to the right and the ovipositor lies almost under the right cercus. Figure 14 represents one of the larger specimens of this species. Besides the thorax and wings, the head and two legs are preserved. On the head can be seen the outline of the two rather large eyes. Toward the front of the head are two small paired bumps and between these a smaller elevation. A line at the top of the head divides the epicranial plates. The pronotum at this stage has rounded angles, a full posterior border, and overlaps the base of the front wings. A pair of elevations is seen close to the median line and near the front of the pronotum. A second pair is placed farther back and out from the median line. The pits observed by Schuchert on *Mylacris (Dipeltis) diplodiscus* are doubtless of the same nature. The front and hind wings are as yet scarcely differentiated from each other either in size or texture. They are still united to the terga by their entire base, although a thickened spot, represented in the drawing, indicates the place at which the articulation of the wing is forming. A delicate

median line divides the thorax, which may denote the line of rupture of the integument in moulting and also that the part preserved is here, as in most instances, the cast-off integument. This line is, however, not more marked than that on the thorax of some living nymphs, resulting from the union of the lateral halves of the terga, and the line along which the break ultimately occurs at the time of moulting. The femur, tibia, and tarsus of the first leg on the right side are preserved. The femur is smooth and of about the same length as the tibia. The tibia, on the contrary, is strongly spinous. The first joint of the tarsus is comparatively long; the others are short. The number of joints in the tarsus can not be made out. The left leg of the third pair shows most of the coxa, the trochanter, the femur, and part of the tibia. The femur is stouter than that of the first pair of legs and is likewise smooth. The tibia is slender and preserves the bases of the spines. The trochanter of this leg, also, is seen as a triangular piece uniting the femur and coxa. As in other cockroaches, a progressive rounding during growth of the posterior border of the pronotum is evident, which gives the pronotum of the adult a circular form. The thin texture and the ornamentation of the pronotum are characteristic and serve to confirm the connection of the nymphs and adults.

The restoration given here (Figure 15), is based on the several nymphs of the species and the adult which served as the type specimen, the pronotum of which, more completely uncovered, is here refigured (Figure 16). The cockroach is represented in the resting position. Spines have not been observed on the femur. That the tibia is spinous is shown, however, in Figure 14. The ovipositor of *E. mazona* was apparently of medium length. At the time the restoration given by Professor Scudder was made (Mem. Boston Soc., vol. iii, pl. x, 1882), the presence of the ovipositor and the spinous character of the tibia were unknown.

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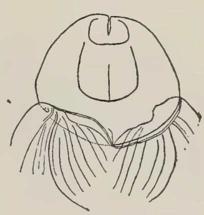

FIGURE 16. — Pronotum of adult of *E. mazona*. × 2.

Formation and Locality.—Coal Measures, Mazon Creek, Illinois.

Etoblattina juvenis sp. nov. Text-figures 17–21.

The most common nymph at the Lawrence locality is a species with large broad abdomen, the terga having well-developed free edges, and the sterna, rounded corners. Two instructive individuals of this species, lying on a small slab, are shown in their relative positions in Figure 17. The dorsal integument of the nymph at the right of the figure has split down the

center and been pushed to each side, thus exposing the basal elements of the legs. The most striking feature is the large size of the second segment,—the trochanter, which, instead of being wedged into the lower angle between the femur and coxa, is apparently joined squarely to the femur. The specimen has been crushed and drawn out laterally, thus causing the trochanters on the left to appear abnormally large and those on the right too small. The median organ in front of the first pair of legs, probably one of the sternal elements, has suffered a similar distortion. The basal part of the ovipositor, 9^{mm} long, is preserved in place. Parts of the body are scattered about

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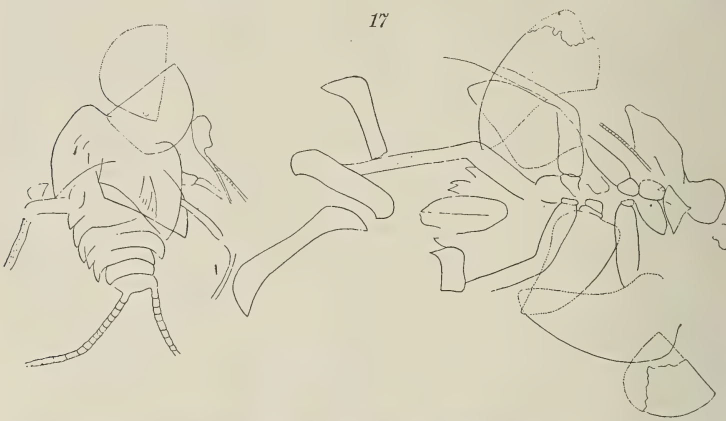


FIGURE 17.—*Etoblattina juvenis* sp. nov.; natural size. Two specimens lying near each other on the same slab. The nymph on the left shows a considerable part of the cerci, which in this species are very long. Both have the legs more or less completely preserved. As a result of crushing, the integument of the nymph at the right has split along the dorsal line, and, spreading laterally, exposed the basal elements of the legs otherwise rarely seen. The species has a large, prominent ovipositor, which is preserved on the specimen at the right; it is badly crushed, however, and its shape poorly defined. Some terga with pointed angles, and sterna with rounded angles, are seen detached and lying between the two nymphs.

Original from the Upper Coal Measures at Lawrence, Kansas, in the writer's collection.

on the slab. Detached terga with their pointed edges, and one of the sterna with rounded edges, are seen lying between the two nymphs. The nymph on the left of the figure is more nearly entire. The head is displaced to the right of the pronotum. The antennæ are very well preserved, but the other structures of the head are too much crushed to be recognized. On the pronotum is seen a circular mark characteristic of the species. Traces of the venation are evident, the cubitus and its branches, as is usual among nymphs, being the most distinct. Parts of the legs are exposed at the sides of the body. The tibia is spinous and the tarsus apparently long. The pointed

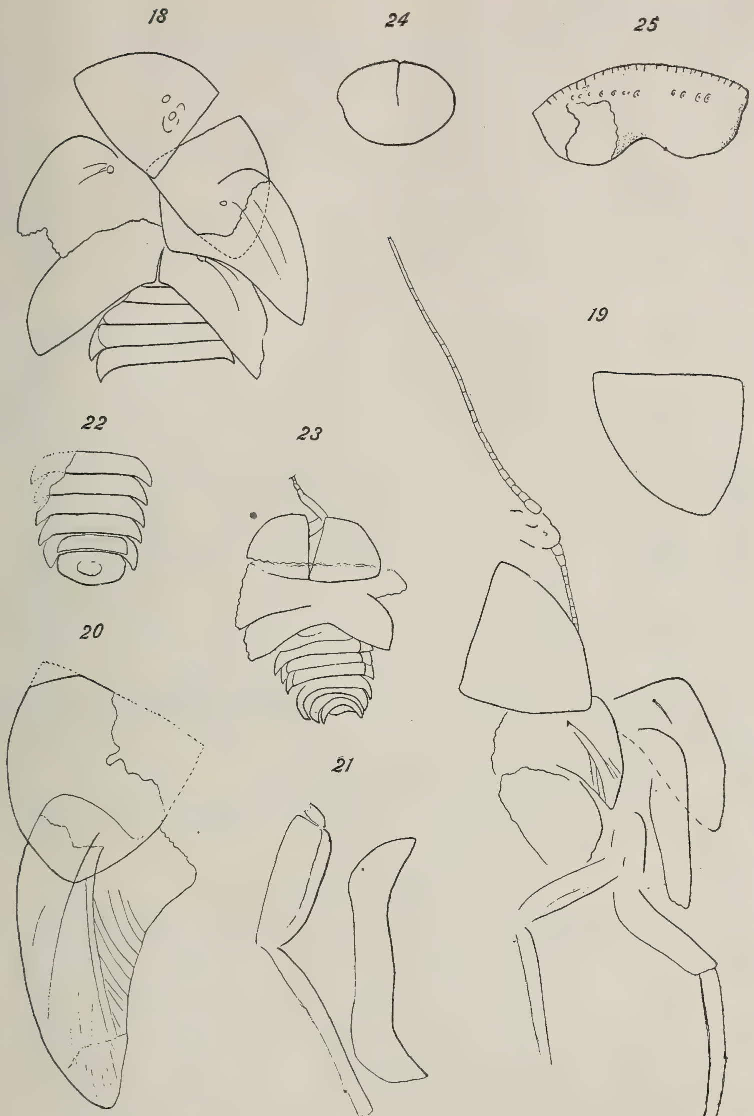


FIGURE 18.—*Etoblattina juvenis* sp. nov. A nymph, of which the thorax and a part of the abdomen are preserved. The abdominal sterna are seen in outline through the terga.

FIGURE 19.—*E. juvenis* sp. nov. A nymph of which a considerable part of the long antennæ and the outline of the head are preserved. The two parts of the pronotum are separated. The absence of spines on the tibia is probably due to imperfect preservation.

FIGURE 20.—*E. juvenis* sp. nov. One wing and half of pronotum of nearly mature nymph.

FIGURE 21.—Trochanter, femur, and one abdominal tergum of nymph.

FIGURE 22.—*Spiloblattina.* Part of abdomen in which are seen indications of color areas resembling those of *Spiloblattina*, to which genus the specimen is provisionally referred.

FIGURE 23.—A small nymph, genus undetermined.

FIGURE 24.—Pronotum of small, probably adult, cockroach.

FIGURE 25.—An undetermined fossil, resembling very much the egg case of cockroaches.

All figures are twice natural size. Original of Figures 18 and 19 in the University of Kansas collection; all others in the writer's collection. All are from the Upper Coal Measures. Figure 23 is from Deer Creek, twelve miles S.W. of Lawrence; others are from Lawrence, Kansas.

free edges of the terga are evident. The cerci, although incomplete, are unusually long. The specimen figured and its counterpart are in the writer's collection. A number of other nymphs of this species have been obtained from the same locality, one of which (University of Kansas collection) is illustrated in Figure 18. The pointed terga and rounded sterna, similar to the detached terga and sternum of Figure 17, are here seen in place. The large nymph, previously figured, is probably also of this species, although the body is larger and more bulky.* The free edges of the terga from the third to the ninth are very prominent. The tenth sternum is rounded. The sterna with their rounded corners are seen in outline through the terga. A part of the strong femur is seen on the right, and a few segments of the antennæ are visible beyond it. The reference of these nymphs to the genus *Etoblattina* is supported by the rounded character of the sterna, which are similar to those of *E. mazona*, and by association, more than half of the adult species from the Lawrence locality belonging to this genus.

Formation and Locality.—Lawrence Shales, Upper Coal Measures, Lawrence, Kansas.

Genus Undetermined.

The generic reference of the small nymph (Figure 23) is in doubt. The abdomen has been torn and crushed, but the ten segments can be made out. A few of the sterna seen in outline through the terga are pointed at their posterior corners. A tibia, tarsus, and a part of the femur lie in front of the pronotum. The number of segments of the tarsus can not be made out, but the claw terminating the foot is preserved.

The pronotum (Figure 24) is found detached, and judging from its rounded form probably belongs to an adult.

Formation and Locality.—Both the nymph of Figure 23 and the pronotum of Figure 24 came from the Lawrence Shales, Upper Coal Measures, Lawrence, Kansas.

* This Journal, vol. xv, April, 1903, pl. vii, fig. 5.

[To be continued.]

ART. XVII.—*A Remarkable Parasite from the Devonian Rocks of the Hudson Bay Slope;* by W. A. PARKS.

IT was the writer's privilege, during the summer of 1903, to be engaged on certain geological investigations in the basin of the Moose river, and the opportunity was afforded to do a small amount of collecting from the Devonian area surrounding the southern end of James Bay. This examination was conducted, more particularly, on the Kwataboahegan river, a stream entering the Moose about 12 miles above Moose Factory, which is situated near the mouth of the great river. An account of the fauna of the Lower Devonian rocks there exposed will appear in the Report of the Bureau of Mines of Ontario for the year 1904. In addition to some new species, described in the article referred to, the attention of the writer was drawn to what appeared to be a new species of Platyostoma with a remarkable surface ornamentation. This fossil, which occurs abundantly, has the shape and general appearance of *Platyostoma lineata*, but the surface differs from that species by the possession of a peculiar reticulated ornamentation.

In nearly all cases, casts only of the numerous gasteropods characteristic of the series are found; only one Platyostoma was collected retaining any trace of the shell which shows the ordinary fine lines presented by *P. lineata*. Among the great number of external casts of this species many were seen to present a constant reticulated appearance, as if the outer ornamented part of the shell had been preserved after the inner layer had been dissolved. Such was the conclusion arrived at in the field; but microscopic examination in the laboratory renders this conclusion very improbable. Many of these external casts show the impression of the lines of growth characteristic of the exterior of *P. lineata*, proving that the structure observed is something entirely external to the shell of the gasteropod, and therefore to be regarded as of a parasitic nature. This parasite is most intimately associated with the shell penetrating into the umbilicus and into the deepest parts of the sutures. This fact makes it very difficult to decide that we are not dealing with an external layer as first suggested.

The lower or basal aspect of the parasite is well seen on the casts of the exterior of the Platyostoma. The outer surface was not observed, as the organism is so persistently imbedded in the matrix as to render all attempts to free it abortive.

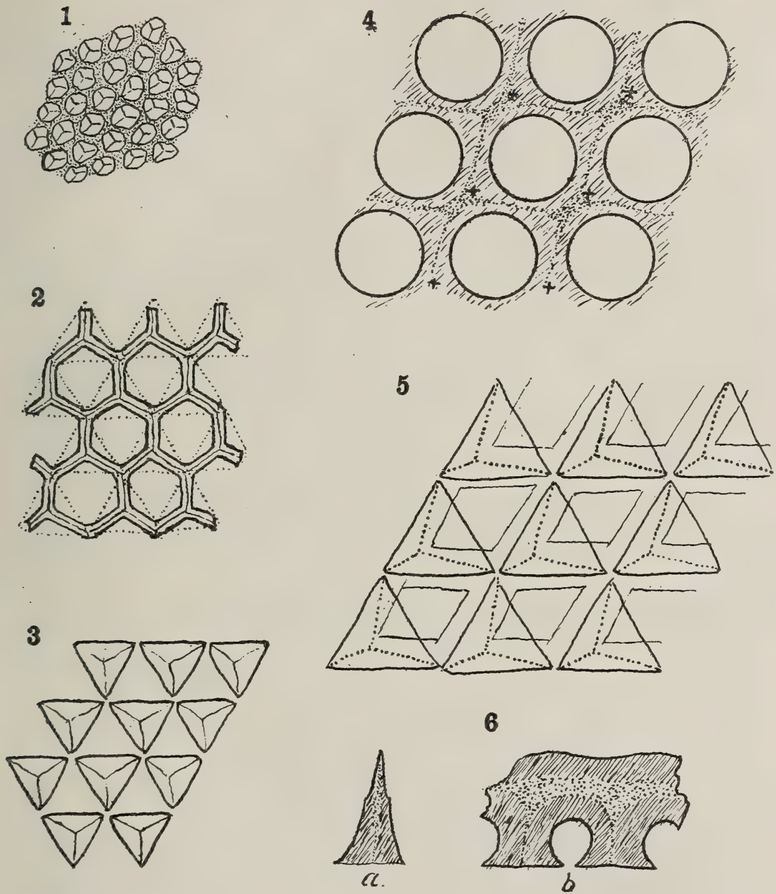
At least two species of this creature occur, differing in the size of the elements composing them and in some minor points

of structure. The finer one is more abundant and better preserved; it is therefore taken as a type of the genus and is described below in some detail.

The cast of the Platyostoma is seen to be covered with round white spots, separated by narrow brownish lines. Three of these spots with the intervals between them occupy the space of one millimeter. They are regularly arranged in lines inclined at a slight angle to the sutures of the host. A line may also be drawn through the centers of the spots inclined at an angle of 60 degrees to the first. On close examination these white spots are found to consist of three elements, separated by minute clear lines. These lines are seen to be uniform in arrangement, being approximately parallel in all the spots; see figure 1. Sections a little higher in the organism show that the pillars decrease in size with a corresponding increase in the intervening matter; they also approach a roughly triangular appearance. Still higher, the contiguous angles of adjacent pillars reach out and unite with each other so as to produce an hexagonal ring with the clear lines of the original pillars forming a continuous line around the middle of the ring. The open center of the ring is occupied by the matrix. It is apparent that each alternate angle of the hexagon represents the position of a pillar, while the other angles are situated at the points of coalescence of adjacent pillars. Higher sections show that this reticulation is continued to the surface of the specimen where the white matter forming the borders of the rings unites and covers the central clear portion. The structure of the reticular network is shown in fig. 2. Tangential sections very near the surface of the reticulation show minute points projecting into the openings of the mesh suggesting the septa of a favositoid coral or certain of the hydrocorallines. A second variety is seen to be represented by an almost similar structure except for the fact that the pillars on ascending become markedly triangular in outline and extremely regular in arrangement. The cross section of this variety at the level where the pillars approach each other is seen in figure 3. The structure of the network is the same as in the first variety. It is quite possible that these two are identical, and that better preservation in the one case has resulted in the retention of the sharp triangular outline of the pillars. It is thought better to include them both in one species.

There is, however, another species, characterized by a much larger mesh in the network and by the fact that the meshes are rhomboidal in outline instead of hexagonal. The ascending pillars show the same three fine clear lines separating the element, but, at a certain level, there is a tendency for one of these lines to become shortened, so that, on the coalescence of

the elements of adjacent pillars, two of the sides of the resulting hexagon are much shorter than the others. A little higher in the skeleton these sides practically disappear, giving in consequence rhomboidal openings in the reticulation. A tangential section of this form is seen in fig. 4, while in fig. 5 is seen a diagrammatic representation of the manner in which the rhom-



boidal meshes originate. In this diagram the center of the pillar is represented by a small cross which will be seen not to conform to the nodes of the reticulation.

In either species it will be observed that the want of symmetry in all directions around the pillars will render vertical sections extremely variable and difficult of interpretation. It is further apparent that vertical sections will cut the reticulated

portion at different points, so that in any one section greatly different appearances will be presented by this part of the skeleton. Vertical sections, however, show that the pillars contract in diameter and the elements composing them gradually arch over and unite, so that certain parts of the network are supported on elliptical arches open at the bottom to the fine brown lines separating the pillars at the base. The interpretation is easy, therefore, that each alternate angle of the hexagonal mesh is supported on a pillar and the alternate angles on a vaulted arch derived from the fused elements of those pillars. Nothing further is revealed by vertical sections, variable as they are, except that the clear matter forming the dividing lines in the pillars expands in the reticulation and ascends almost to the surface of the network, where it is covered by the white matter forming the sides of the meshes. Vertical sections are shown in fig. 6.

The thickness of the entire encrustation in the hexagonal variety is about three-fourths of a millimeter. The rhomboidal species attains a greater height, possibly as much as two millimeters.

The zoological affinities of these parasites is somewhat difficult to determine. The regularly reticulated skeleton at first suggests the Bryozoa, but the peculiar support on the pillars and the structure of the skeletal matter are features that must remove the organism from that association.

The occurrence of the parasite on shells of gastropods naturally leads one to the consideration of Hydractinia, and it is highly probable that our species are closely related to that organism.

Tangential sections of Hydractinia show a network of chitinous fibers with round pillar-like elements at the nodes. The nearer to the base that such sections are prepared the more pronounced are the regularity of the mesh and the individuality of the pillars. Higher sections show that the reticulation becomes more and more irregular as we approach the surface. In the short time spent in examining the skeleton of Hydractinia the writer was unable to cut tangential sections low enough to cross the pillars below the first connecting bars, so that a similarity of mode of attachment can not at present be urged in support of the relationship of our species to Hydractinia.

The two organisms, however, agree in the possession of distinct ascending pillars which give rise to a pronounced reticulation by the coalescence of horizontal elements derived from those pillars. A distinct difference is seen in the fact that our species produce but one layer of meshes which has a considerable vertical extent, whereas Hydractinia repeats this process

and in a more and more irregular manner as it increases in age. Further, the meshes of the network in Hydractinia are practically without any tendency to form tubes, i.e. have no vertical extent. No evidence of polymorphism is to be observed in the species under review. Another point of similarity is seen in the fact that the base of a Hydractinia colony shows a more resistant brownish layer where it is attached to the host; the brown matter lying between the bases of the pillars in our species may well be analogous to this structure in Hydractinia.* The presence of the minute septa-like projections near the surface of the network suggests that the openings of the meshes were occupied by individual hydroids with very short vertical extent. Such an interpretation would place the creature near to Professor Duncan's Stoliczkaria. This relationship can, of course, be maintained only on the supposition that the coenenchyma of Stoliczkaria is entirely unrepresented in our species.†

There is little doubt, therefore, that the new genus may be safely placed under the Hydroida with a considerable resemblance to Hydractinia and a suggestion of the structure of Stoliczkaria. If this relationship is accepted, the study of the present species throws considerable light on the manner in which the horizontal elements arise from the ascending pillars in all this class of creatures. Further, we have but to assume the closing in of the meshes and the repetition of the process of growth to arrive at the origin of the skeleton of that large and diverse group, the Stromatoporoidea.

The preferential parasitism exhibited by this organism at so low a stage as the base of the Devonian is a matter of interest. Further, if we accept its hydroid affinities, and omit the graptolites and stromatoporoids, we have in this creature the earliest of the Hydroida, excepting, of course, the very doubtful Corynoides and Palæocoryne.‡

Tristylotus gen. nov.

Encrusting parasite on species of Platyostoma. Skeleton probably chitinous or partially calcified, consisting of a continuous polygonal reticulation, supported on short pillars. These pillars are composed of three elements, are sub-circular at the point of attachment and triangular above. The reticulation arises by the drawing out of the angles of the triangular pillars and the coalescence of the points thus produced.

Tristylotus—*στυλωτός*, supported on pillars.

* Nicholson & Lydekker—Manual of Palæontology, Vol. I, p. 198.

† Ibid., p. 228.

‡ Ray Society for 1870. Monograph of the Tubularian Hydroids, George James Allman, M.D., p. 170 et seq.

Tristylotus hexagonus sp. nov.

The meshes of the network are hexagonal and small.

Tristylotus rhomboideus.

The meshes of the network are rhomboidal and larger.

The writer is indebted to Professor Ramsay Wright of the University of Toronto for suggestions regarding the affinity of Tristylotus and for the coining of the generic name.

DESCRIPTION OF FIGURES (p. 137).

Tristylotus hexagonus

Fig. 1.—Base of the parasite as it appears on the external cast of Platyostoma. Enlarged 30 times.

Fig. 2.—Diagram to show the origin of the hexagonal network from the triangular pillars. The orginal position and the outline of the pillars are shown in dotted lines. The fine lines show the clear central portion of the mesh. Enlarged about 75 times.

Fig. 3.—Cross section of the pillars in one variety at a level just below where they begin to unite. Enlarged 75 times.

Fig. 6.—(a) Vertical section through a pillar in a direction across the web of the network. (b) Vertical section through two pillars in a direction following the web of the network. Dotted part is the clear central portion. Striated part represents the white matter. Enlarged 30 times.

Tristylotus rhomboideus

Fig. 4.—Tangential section through the reticulated portion. The positions of the centers of the pillars are indicated by small crosses. The dotted portion represents the clear tissue and the striated portion the white matter. The openings in the meshes are shown round in the diagram ; this is not strictly correct, as they conform more or less to the shape of the mesh. Enlarged about 60 times.

Fig. 5.—Diagram to illustrate the origin of the rhomboidal meshes. The pillars are indicated by heavy lines. The dotted lines represent the clear lines dividing the pillars into three parts. One of these lines is seen to be much reduced in length. It is this shortening that results in the formation of rhomboidal instead of hexagonal meshes. The outlines of the resulting rhomboidal meshes are shown in fine lines.

Art. XVIII.—*Asterolepid Appendages;* by C. R. Eastman.

The renewed interest which has become manifest in the study of the earliest known fish-like vertebrates bids fair to lead to a clearer understanding of the problems presented, if not indeed to their immediate solution. One of the most puzzling riddles is that concerning the derivation and homology of the pectoral limbs, or "swimming appendages" of the *Asterolepidæ*, the only family of Ostracophores in which such organs occur. Different interpretations of their nature have led to a wide range of opinion in regard to the relations of Ostracophores in general, some authors uniting them with fishes proper and others separating them, some deriving them from the Elasmobranch stem, some from the Crossopterygian, and some even from Arachnids. It is still a mooted point whether Ostracophores and Arthrodires are genetically related, some favoring the retention and others the abolition of the group *Placodermata* as originally proposed by M'Coy. It is upon controverted questions of this nature that a study of Asterolepid appendages may be expected to throw some light.

A variety of opinions has been expressed concerning the probable origin and homology of these organs. Thus, there may be noted: first, the theory that they partake of the nature of Arthropod appendages, on the assumption that Ostracophores are descended from Arthropods; secondly, the theory which explains Asterolepid limbs as the produced and jointed head-angles, or "cornua," of forms like *Cephalaspis;* thirdly, the theory that they are derived from a fixed spine attached to the body, similar to the spinous appendage of *Acanthaspis;* fourthly, the theory that they are derived from the lobate Crossopterygian pectoral fin by a process of reduction and specialization; and lastly, the theory that they are independently derived.

The first two of these hypotheses are evidently founded upon complete misconceptions of the structure and position of Asterolepid limbs, and may be summarily dismissed. The third, which explains them as having become evolved from a fixed spine, presupposes anomalous, if not impossible conditions. Neither can they be looked upon as modified pectoral fin-spines, the remainder of the fin having become atrophied; for no similar case of reduction is known amongst fishes. The fourth suggestion, that these members are derived from specialization of Crossopterygian pectoral fins, has recently been put forward by Mr. C. Tate Regan,* and has not yet been discussed. The foremost objection that may be urged against this theory is that it

* Regan, C. T., The Phylogeny of the Teleostomi (Ann. Mag. Nat. Hist. ser. 7, vol. xiii, pp. 329–349), 1904.

rests upon the unproven hypothesis that Asterolepids are highly modified Crossopterygians. Or, to state the converse proposition, the theory that these two groups are genetically related depends upon whether the modified limbs of the one can be homologized with the lobate pectoral fin of the other, there being absolutely no other characters which can be said to indicate community of origin.

The absence of a lower jaw in Ostracophores, the dissimilar arrangement and structure of their head-bones, armouring of the body, single dorsal fin without either dermal rays or basal supports, heterocercal tail, and absence of both pelvic and pectoral girdles, are characters which emphasize the violent contrast between forms like *Pterichthys* and Crossopterygians. That the latter are descended from a heterocercal ancestor is not to be questioned, but if we admit the soundness of Mr. Regan's conclusion that Asterolepids are highly modified Crossopterygians, how are we to explain their reversion to the primitive heterocercal condition, after having passed through the homocercal? The anterior pair of limbs could hardly have become so highly modified, without the hinder pair having also undergone specialization. But even assuming, for sake of argument, that the pelvic fins have become lost, we should expect to find remnants of a girdle, and in any case some indication of a pectoral arch, corresponding to these structures in Crossopterygians; whereas in fact we do not.

The Asterolepid paddle is not made up of articulated rays, but is simply a muscular extension of the body encased in dermal plates. An appendicular skeleton is wanting, and the external covering plates are attached to the body-armour by a complicated joint, one of the dermal plates being pierced for the passage of nerves and nutrient canals; hence it is clear that in structure and mode of attachment these limbs differ radically from normal Teleost conditions. The fact that Ostracophores possess a much greater antiquity than Crossopterygians also militates against the assumption that they are modified descendants of the latter. It is likewise impossible to reconcile the geological occurrence of the groups to which *Cephalaspis* and *Pterichthys* belong with the view expressed by Mr. Regan that the former is a specialized Asterolepid.

There remains finally the theory, which appears to be not very generally accepted, that Asterolepid limbs have been independently derived. The absence of an appendicular skeleton, and the peculiar mode of attachment of these organs, offer such striking contrasts to the fins of fishes as to make it impossible to conceive of a homology existing between them. Moreover, paired appendages are absent, so far as known, in all other Ostracophores. Either they were formerly present, and

have become lost through atrophy, or else they were never developed except amongst Antiarcha; and if the latter be true, it is easy to see that Asterolepid appendages are unrelated to the fins of fishes, since they originated in a different way and are constructed upon a different plan. They may be regarded with much probability as having developed from a muscular flap, or integumentary extension of the body, being of kindred nature with tactile or clasping organs, or with the frontal spines of Chimæroids. The fact that one of the dermal plates is pierced and otherwise modified for their attachment would seem to indicate that *pari passu* with the development of body-armour, the paired muscular extensions also became encased in plates. But sphinx-like though the problem be as to how and when these structures originated, the evidence appears tolerably certain that they have not been derived from the fins of Pisces proper.

A word may be said in regard to the assumed "close relationship of the *Coccosteidæ* and *Asterolepidæ*," these families being representative of groups which are united by Mr. Regan, together with the Osteostraci, in a single order of Teleostomi. We regard as abortive this author's comparison of *Coccosteus* with *Pterichthys*, which leads him to the conclusion that "the arrangement of the bones of the head, and especially that of the dermal plates of the body, can easily be reduced to a common plan"; and it is manifestly untrue that "in the arrangement of the bones of the cranial roof *Coccosteus* is almost a typical Crossopterygian." A remote superficial resemblance there may be, in that certain plates are symmetrically disposed with reference to the median line, but no real homology can be claimed to exist between the cranial elements of *Coccosteus* and those of Crossopterygians and Stegocephalians. It is impossible to insist too strongly that the jaw-parts of Coccosteids are totally distinct from those of fishes proper, although a parallel exists between them and the dental plates of Palæozoic Chimæroids. Both the upper and lower jaw of Arthrodires consist of purely dermal ossifications, and teeth, properly speaking, are absent. As for the serrations which sometimes occur along the cutting margin in one or both jaws, and function as teeth, these are not structurally differentiated from the supporting bony tissue. Moreover, the lower dental plate ("gnathal" of Dean), instead of being articulated to the cranium, is suspended freely in the soft parts, similarly as in Chimæroids. There is no evidence of pectoral fins amongst Arthrodires, and the lateral spine which is attached to the ventral armour evidently has nothing in common with the pectoral limb of Asterolepids.

The axial skeleton of *Coccosteus*, as depicted by Jækel* with

*Jækel, O., Ueber Coccosteus und die Beurtheilung der Placodermen (Sitzungsber. Gesell. Naturforsch. Freunde, p. 111), 1902. —— Ueber die Ruderorgane der Placodermen (*ibid.* pp. 178–181), 1893.

its complement of ossified ribs, has a purely mythical existence. There are no vertebral rings, the axis being entirely cartilaginous, and on either side of this occur the neural and hæmal arches. It is the latter which Jækel has represented as ribs. Neither is there a pelvic girdle, as claimed by this author, his so-called "ileum" being erroneously interpreted as such, and inverted in position. The narrow, rod-like portion, instead of being directed dorsally, and attached to the cartilaginous axis, in reality projected outward from the body-wall, being in fact merely a modified anterior fin-ray. There is a well-preserved specimen in the Paris Museum of Natural History which shows these structures in their natural position, followed by the remaining fin-rays in regular sequence; nor is this the only example which confirms the interpretation here given.

Another notable difference between Arthrodires and Asterolepids consists in the structure of the dermal plates covering the head and anterior part of the trunk. The body-armour of Asterolepids very likely originated from the fusion of scales, but Arthrodires are naked without exception, and it can be demonstrated that their dermal plates arose within the integument from secretions on both sides of the initial layer. The process was continuous throughout life, a succession of tuberculated strata being deposited upon the external surface of the earlier formed laminae, and bony tissue being added underneath, also in regular layers. Altogether, the distinction between Arthrodires and Ostracophores is so trenchant and far-reaching, that the revival of the group "Placodermata" for their union appears to be an unwarranted and decidedly retrograde movement. Finally, we must beg to differ from Mr. Regan in his conclusion that "the *Coccosteidæ* are Teleostomi, that the *Asterolepidæ* are allied to the *Coccosteidæ*, and that the *Cephalaspidæ* have been derived—through the *Tremataspidæ*—from the *Asterolepidæ*," this view being unsubstantiated by either morphological or palæontological evidence, and contrary to all probability. Nor can we view with much favor Jækel's extraordinary hypothesis* that Coccosteans are ancestral to Chimæroids.

Harvard University, Cambridge, Mass.

* Jækel, O., Ueber Ramphodus, etc. (Sitzungsber. Gesell. Naturforsch. Freunde, p. 392), 1903.

ART. XIX.—*Electrotropism of Roots;* by AMON B. PLOWMAN. (Preliminary Communication.)

IN a brief report some two years ago on the relations of plant growth to ionization of soil* it was suggested that the turning of root tips toward the anode is most easily accounted for by attributing this reaction to the effect of the electrons, or electric charges of the ions, rather than to any mere chemical effects of the atoms.

Since the publication of that report an extensive study of electrotropic phenomena has been carried on at the Memorial Research Laboratory of Harvard University. The results seem to indicate that the explanation advanced in the above-mentioned paper is entirely correct, and further, that the conclusion that "negative charges stimulate, and positive charges paralyze, the embryonic protoplasm of plants," is well founded.

Many kinds of seedlings have been grown both in ordinary soil and by the water-culture method in the presence of an electric currrent, under the most widely varied conditions of temperature, current density and culture composition, with results which are altogether uniform in kind. Even the least perceptible current passing by the roots will in time overcome their normal geotropic tendency, and will turn their tips toward the anode. The passage of a comparatively strong current for only a few minutes will produce a marked curvature after two or three hours. Vigorous roots have been deflected 90° from their downward course in half an hour by a moderately strong current. In such a case as this, if the current is kept on, the roots grow horizontally toward the anode, while if the current is turned off they either continue curving until a complete coil is formed, or they may gradually bend downward again, forming a double curve. In any case the region of the initial curvature is dwarfed in its growth and does not become nearly as large in diameter as the parts either above or just below. There is also always a flattening of the root on the concave side of the curve. This flattened region always remains white when the root tips are fixed in Flemming's fluid, while the other parts, like normal roots, are blackened by a prolonged action of osmic acid solutions.

A study of the histology of such electrically curved roots shows that the protoplasm on the side nearest the anode has been coagulated and killed by the action of the current. The cells are completely plasmolyzed, and their walls are exceed-

* This Journal, xiv, p. 131, Aug. 1902.

ingly thin and much crushed. Where the root has been acted upon for but a very short time only a few of the cortical cells are affected, while for longer action of the current, or more intense current, the affected zone grows wider and wider, until it may involve the entire structure of the root. In every case the boundary line between the affected zone and the normal part is practically a straight line exactly at right angles to the path of the current. The effect is of course most pronounced in the region of most rapid normal growth. Very weak currents tend to check growth in length, and the roots consequently take on a more stocky appearance. They are often actually thicker than the normal roots of the control.

That the results of these experiments are to be attributed to purely chemical causes is rendered highly improbable by the fact that the results are practically uniform, no matter what the ions of electrolysis may be. Distilled water, very dilute acids, bases, and neutral salts all are apparently alike in this relation, their effects differing only with their varying electrical carrying power. Whatever may be the relation of mass action and of chemical and physical affinity to growth under normal conditions,* it would seem that in the present case the all-important factor is the electron or electric charge of the ion, and, more specifically for our purpose, the positive electron, since it is this one which produces the most striking effects. And so far as is at present known, those effects are always in the same direction, viz: paralysis or actual death of the protoplasm exposed to the action of a positive charge. As for the negative electrons, it seems safe to say that in the majority of cases they are neutral in their relation to living cells, and where any effect is perceptible it is in the way of stimulation of the protoplasm.

There is now in preparation for publication in this Journal a fully illustrated report of this series of experiments, together with a consideration of the practical and theoretical bearings of the facts involved.

Phanerogamic Laboratories, Harvard University, June 1904.

* See the article by J. B. Dandeno, this Journal, xvii, pp. 437–458, June 1904.

ART. XX.—*On the Oxygen Absorption Bands of the Solar Spectrum;* by O. C. LESTER.* (With Plates II, III and IV.)

THE present research was undertaken with the object of investigating as fully as possible the structure and extent of the oxygen absorption spectrum. This includes a study of the relations existing between the lines of a band and also between the several bands, taking into account those groups above *a* which do not seem to have been considered before. In order to do this satisfactorily it was necessary to have very accurate measurements of the wave lengths. The best determinations previously made are those of Rowland and Higgs, but neither gives all the lines even of the groups A, B, and *a*. Rowland's measurements are nearly complete for B, but he gives only a few for the other two groups. Higgs gives A and B and up to the ninth pair of *a*, and although he and Rowland agree remarkably well in general upon B, judging from the few lines in A which both have measured the agreement is not so good, there being much greater discrepancies than one would expect from the accuracy claimed for their measurements. Hence it seemed worth while to make new determinations of all, or nearly all, the lines previously measured, and in addition many new lines are given. It is hoped, therefore, that the present determination of the wave lengths, taking into account the best previous results, have both extended and unified the measurements on these bands and rendered them, on the whole, more accurate; thus doing for the absorption spectrum of oxygen what a similar work of M. Eisig† has done for the line spectrum.

Because of the precision which it is possible to attain in the measurement of this spectrum, a careful study of the relations subsisting between the lines and bands furnishes an excellent test of the so-called laws of Deslandres for band spectra. They are briefly as follows:

1. In a given band the intervals from one line to the following in any series, calculated in vibration numbers, are in arithmetical progression, i. e., the lines are connected by a relation of the form

$$\frac{1}{\lambda} = \mathrm{N} = a + bn^2$$

* Abstract of a thesis presented to the Philosophical Faculty of Yale University, June, 1904, for the degree of Doctor of Philosophy. The paper will appear *in extenso* in the September number of the Astrophysical Journal.

† M. Eisig: Das Linienspektrum des Sauerstoffs, Wied. Ann., li, 1894.

where a and b are constants and n takes on all integral values from 0 to n.

2. When several series arise from the edge of a band they are similar in all respects, and all bands belonging to the same substance have the same number of series.

3. In a series of bands the vibration numbers of the edges form a series similar to that of the lines in a single band.

These laws are the most general in their application that have yet been announced. Deslandres tested them on many spectra, although he never published details showing the exactness of agreement. Kayser and Runge* have obtained a general confirmation upon bands of many substances, including those of N, C, CO, CN, and I, but the laws do not apply equally well to all cases and occasionally appear to degenerate into mere interpolation formulæ. The difficulties in the way of obtaining more exact expressions for the laws are in measuring the wave lengths of bands accurately enough to warrant taking into account small variations of the reciprocals, and, in the case of the third law, in finding a long enough series of bands capable of precise measurement. Most of the bands hitherto investigated are in the upper part of the spectrum, where a small error in the wave length causes a large error in the reciprocal.

Measurement of Wave Lengths.

In the measurements of Rowland and Higgs to which reference is made above, both use the same unit, viz. 10^{-7} mm., and their results appear to be equally accurate. For those lines in B and a which both have measured and for which the agreement is ·01 of a unit or closer, the value adopted in the present work is the mean of the two. In case the disagreement is greater than one would attribute to errors of observation, the value adopted is the mean of my own final result and the one which it confirms, provided such agreement is decidedly stronger with one than with the other. In some cases the mean of all three measurements was taken. For the large majority of the lines in A and a the values given are the means of my own and Higgs' results alone. Those of a' and a'' have not been given before. Since ·01 of a unit is about the limit of accuracy in general, it has been thought best to retain only two decimal places in the wave lengths except in the case of B, where many of the lines are taken as Higgs and Rowland give them. It may be added further that the third decimal place rarely affects even the seventh place of the reciprocal.

* Ueber die Spektren der Elemente: Abhandl. der Berl. Akad., 1888–92.

The measurements of the stronger lines were made as usual with a micrometer microscope. Some of the weak lines had to be strengthened by a fine mark placed on the back of the negative. Others were measured from Rowland's charts, care being taken to set on the center of density of the lines. This last method is better for weak lines, although even here a fine mark must sometimes be used, as any magnification by the micrometer causes some of them to melt into the background.

The group a' was first noted by Jewell.* In the "head" or first band of this group, many of the lines appear double and some foreign lines seem to be present. The line 5789·40, which is the "chief line" of this band corresponding to similar lines in A, B, and a, has been assumed double, as it is in all the other bands. The only indication of being double actually shown is its greater intensity and a certain flatness of the intensity curve characteristic of close doubles. The uniformity of the two series also calls for a close double at this place.

The approximate positions of many of the lines in the group called a'' were calculated from relations established between the other groups, the observed values differing by less than ·2 of a unit from the calculated. The lines are all extremely weak. Some, though not all of them, appear on negatives taken in zero weather, which indicates that they are not water-vapor lines. The first band of the group begins as usual with a double line, possesses a chief line and a final pair in its proper position, as a glance at the groups as shown in Plate III will show. Probably not all the lines present can be seen. Many are so faint as to be visible only on the charts and then only when they are held in particular positions with respect to the light. Some of the lines are stronger on the corresponding chart of Rowland's first series, which is more intense than the second. No attempt has been made to measure many of the lines of this group closer than the nearest half-tenth, which is readily done by estimation. Blunders and mistakes in calculation for all groups except A have been practically eliminated by the use of verniers made to fit Rowland's charts, which, in spite of irregularities in the map scales, enabled any but small mistakes to be detected at once.

* The Absorption Spectrum of Oxygen; Astron. and Astrophys., xii, 1893.

TABLE I.

Note.—Each band contains two series which go by pairs. Consequently to obtain a single series of a band alternate numbers must be taken.

A		B	
First band.	Second band.	First band.	Second band.
7594·00	7621·27	6867·458	6884·080
95·27	23·53	68·457	86·004
94·28	24·77	67·794	86·982
95·55*	27·30	68·780‡	89·183
94·81	28·52	68·337	90·144
96·06	31·28	69·338	92·614
95·55	32·49	69·144	93·559
96·79	35·47	70·130	96·282
96·51	36·65	70·220 §	97·197
97·74	39·86	71·180	6900·196
97·70	41·01	71·528	01·116
98·90	44·46	72·489	04·363
99·14	45·59	73·078	05·263
7600·30	49·27	74·039	08·785
00·80	50·40	74·888	09·677
01·95	54·33	75·830	13·449
02·65	55·45	76·953	14·331
03·80	59·62	77·878	18·365
04·73	60·73	79·275	19·245
05·87	65·14	80·173	23·542
07·05	66·25	-----	24·416
08·20	70·89	-----	28·986
09·57	71·97	-----	29·839
10·72	76·86	-----	34·669
12·33	77·92	-----	35·518
13·45	83·06	-----	40·584
15·32	84·11	-----	41·430
16·41	89·47	-----	46·770
----	90·50	-----	47·580?
----	96·11	-----	-----
----	97·13	-----	-----
----	03·02	-----	-----
----	7704·02 †	-----	-----
----	10·16	-----	-----
----	11·16	-----	-----
----	17·60	-----	-----
----	18·55	-----	

* Higgs gives also 95·42 and 95·66; probably outside edges of this line.

† These lines taken from Higgs' measurements, and from the uniformity of the series preceding they appear a little large.

‡ This line apparently double.

§ These lines constitute the so-called "chief line." Components difficult to measure accurately.

α		α′	
First band.	Second band.	First band.	Second band.
6276·81	6287·94	5788·33	5796·30
77·66	89·60	(88·55)§	97·76
77·03	90·42	89·00 (double?)	98·43‖
77·86	92·35	88·75	5800·18
77·52	93·15	89·40 (chief line)	00·83
78·29*	95·36	89·40	02·87
78·29	96·34	(89·71)	03·51
79·07	98·64	90·07	05·84
79·31	99·41	90·32 (double ?)	06·47
80·08	6302·18	90·97	09·10
80·61	02·95	91·49	09·72
81·37	06·00	(91·78)	12·64
82·16	06·75	92·15	13·25
82·93	10·06	92·96	16·46¶
84·00	10·81	93·60	17·07
84·75	14·40	----	20·58
----	15·14	----	21.16
----	19·02	----	24·94
----	19·75†	----	25·52
----	23·92	----	----
----	24·64	----	----
----	29·10	----	----
----	29·82	----	----
----	34·55	----	----
----	35·26‡	----	----
----	40·28	----	----
----	40·98	----	----
----	46·27	----	----
----	46·96	----	----

α″	
First band.	Second band.
5377·20	5384·27
77·32	85·45
78·00	86·05
78·38 (chief line)	87·50 (double?)
79·45 (double?)	88·10**
80·00	{ 89·85 } ††
80·20 (double ?)	{ 90·45 }
80·85 "	92·55 (covered)
81·40	93·10**
81·97	95·55
	96·10

* Chief line and evidently a close double. Higgs gives also 78·19 and 78·38, apparently the outer edges.

† End of Higgs' measurements. ‡ This line hidden by adjacent heavy line.

§ Lines bracketed do not appear to fit the series. Perhaps foreign.

‖ Covered by heavy line. ¶ Hidden by heavy adjacent line.

** Stronger on old chart.

†† Hidden by a group of five heavier lines, none of which actually cover the positions but the shading renders them invisible.

Relations between Lines and Bands.

The terms "head" and "tail" or "train" used to designate the two parts of the A, B, and *a* groups cannot be taken in this case in the usual sense of these terms as applied to band spectra, and are really misnomers. The spectrum is composed of two series of entirely separate bands instead of a single series, the so-called "heads" forming the first and the "tails" the second. The first series has the appearance of being nearly all "head" and the second all "tail," but the apparent crowding and confusion in the case of the former is due to the distance between the first few pairs being less than their width. That the "head" and "tail" are really separate bands is apparent from the following considerations.

Both "head" and "tail" begin with pairs of the same width, which decrease in width with increasing wave length in the same manner.

No series in a "head" or "tail" is a continuation of a series in the other as it should be if they were parts of the same band. Also, the first and second differences between homologous lines in the "heads" and "tails" form entirely different series as do the ratios of the homologous lines. Further, while there are no lines in places calculated for the tail series extended upward, faint lines appear to be in the proper places for an extension of the head, just as if the first band, instead of fading out gradually as the second does, should drop very suddenly in intensity on approaching the region occupied by the second. That this is apparently what happens is indicated also by the fact that the last line of what is usually considered the last pair in the "head" of B is scarcely half the intensity of its mate and in *a* is less than half. Extending the series of the first bands of B and *a* we find the following agreement between observed and calculated values.

B		α	
Observed.	Calculated.	Observed.	Calculated.
6879·28 } *	----	6284·00 } *	----
80·17 }	----	84·75 }	----
81·80	81·85	86·09	86·11
82·72†	82·72	86·88	86·84
84·65	84·67	88·48	88·49
85·54	85·52	89·20	89·20
87·75	87·74	91·14 (covered)	91·14
88·60	88·57	----	91·83
91·05	91·06	----	----
91·87	91·87	----	----
94·67	94·63	----	----
95·50	95·42	----	----

* Last pair of strong lines. † Hidden by heavy adjacent line.

Indications that the first A band is continued beyond the last strong pair are not lacking though they are not so strong. The other groups are too faint for corresponding lines to be observed in them.

The geometrical relations of both lines and bands are clearly seen in Plates III and IV.

In most spectra it is the vibration numbers which are subject to regular laws rather than the wave lengths, but in this case it makes little difference so far as Deslandres' first law is concerned, which is taken. The first law is but a rough approximation, as is shown by the following application to the second series of the second band of B. The constant b is calculated from the sixth line.

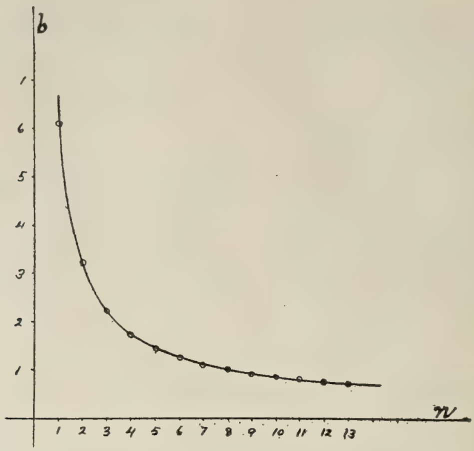
$\frac{1}{\lambda}$ observed.	$\frac{1}{\lambda}$ calculated.	Diff.
14526·27	14526·27	0·00
520·15	524·84	+ 4·69
513·49	520·53	+ 7·04
506·29	513·36	+ 7·07
14498·65	14503·33	+ 4·68
490·42	490·42	0·00
481·70	474·65	− 7·05
472·45	456·00	−16·45
462·72	424·49	−38·23
418·53	319·67	−98·76
406·26	292·92	−123·34

The accuracy of the measurements would allow a variation of only a few hundredths in the last column. The fact is, Deslandres' constant b is not really a constant, at least for this spectrum, as the following values of b, calculated for the different lines of the above series, show:

$b =$ −6·12	when $n = 1$	$b =$ −1·098	when $n = 7$
−3·195	"	−0·993	"
−2·22	"	−0·911	"
−1·726	"	−0·846	"
−1·434	"	−0·792	"
−1·238	when $n = 6$	−0·748	"
		−0·710	when $n = 13$

The variations of b are the same for all the bands, except that for the second band series the initial values are always larger than for the first. Also, the values of b for homologous lines of the same band series are nearly constant.

If the values of b for any series are plotted as ordinates and the values of n as abscissæ, curves are obtained which at once suggest a much better law.



The bn-curve for sec. series, sec. band, Group B.

The curve, in form, is very nearly an equilateral hyperbola. Assuming it to be such we have

$$bn = k = \text{const.}$$

This, however, is not quite true, but if a correction is made as follows,

$$bn - \frac{n}{c} = k$$

then k is almost exactly constant. Substituting this value of b in Deslandres' formula we have

$$\mathrm{N} = a + kn + cn^2.$$

That is, the correction for Deslandres' law is of the first order in n instead of being as usual of a higher order; the constant k is very large compared with c. Both c and k are different for the different series but their variations are small.

The increased accuracy of the new formula is shown by its application to the same series of B calculated above by Deslandres' law. The differences only are given here corresponding to the third column above.

0·00	+0·01	$k = 5{\cdot}86$
+0·00	−0·04	$c = {\cdot}2611$
+0·02	−0·07	
+0·05	+0·01	
+0·00	−0·02	
+0·02	−0·05	
+0·01	−0·16	

The second differences of the new formula are constant as they are in that of Deslandres, and it is evident from the near approach to constancy observed in the second differences of both N and λ, that some law based on this property is the true one. That the lines follow some very definite arrangement is seen from the smoothness of the bn-curves and from the smallness of the differences between the observed and calculated values. It is quite probable that the proposed formula will be found to represent the line series of other band spectra more closely than the old. This I have not as yet investigated. Assuming the proposed law to be exact we have on the other hand a criterion of the accuracy of the measurements of the wave lengths. It is quite likely that if the series were longer the formula would need an additional term, possibly one depending on the wave length. This is a matter for further investigation. The formula may have some theoretical importance also, as the formulæ so far deduced theoretically have not contained the first power of n.

Deslandres' second and third laws are only approximate for this spectrum but a correction for them could not be obtained with certainty, owing, in the case of the third law, to the shortness of the band series.

The points of chief importance in the foregoing discussion may be summarized as follows:

1. The general accuracy of the determination of the wave lengths in the groups A, B, and a has been greatly increased and the series which compose them considerably extended.

2. The band a' has been measured and its relation to the other groups studied for the first time, and in addition a new band a'' has been observed and studied at $\lambda = 5377 \cdot 2$.

3. The oxygen absorption spectrum has been shown to consist of two distinct series of bands instead of one, the series of bands occuring in pairs just as do the series of lines in a band.

4. Deslandres' first law has been shown to be entirely inadequate to represent the line series of the several bands and a modification is proposed which gives results agreeing with the observed values to about the limit of error of the measurements.

In conclusion I wish to express my thanks to Prof. A. W. Wright, whose kindly interest and criticism have been of great benefit throughout this investigation, and through whose aid the excellent photographs of the spectrum were obtained.

Sloane Physical Laboratory, Yale University.
May 1, 1904.

EXPLANATION OF PLATES II TO IV.

Plate II.

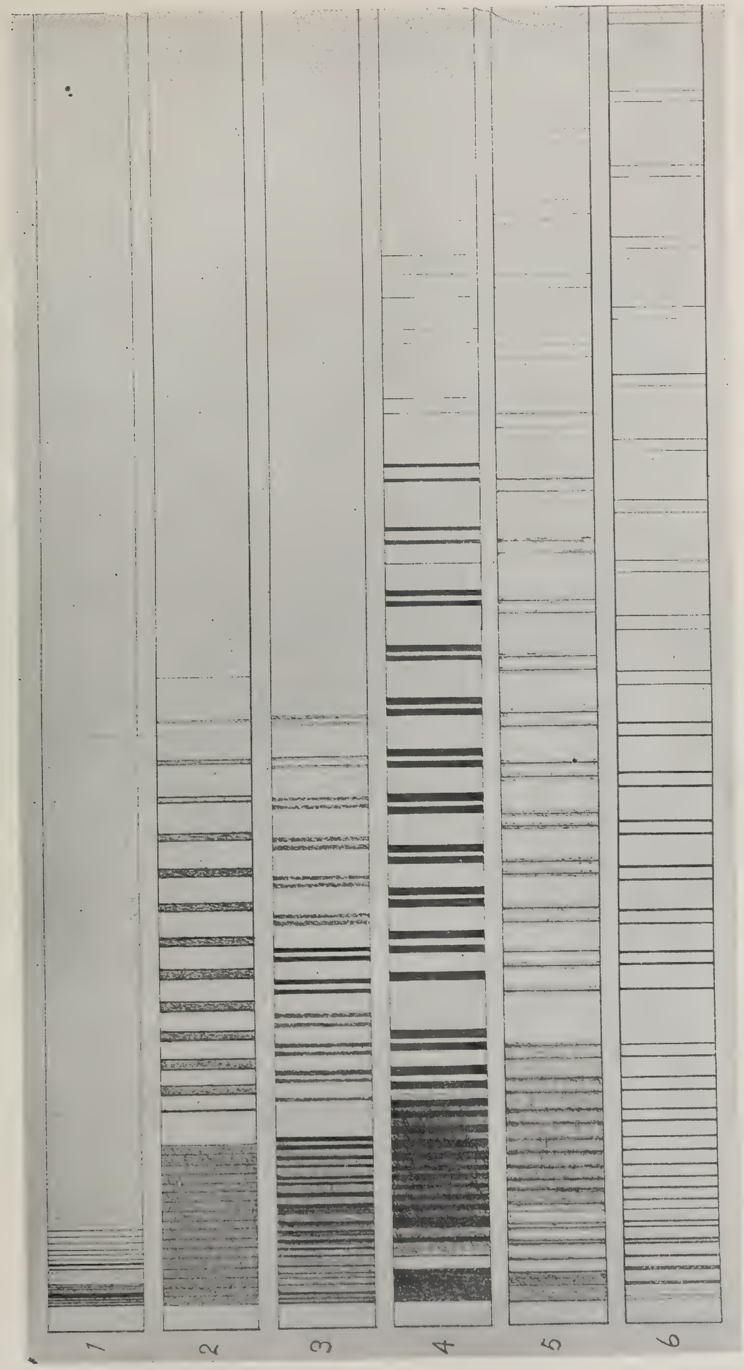
1.—A group ; Kirchhoff. Prismatic spectrum.
2.—A " ; Thollon. " "
3.—A " ; Langley. Grating spectrum.
4.—A " ; Piazzi Smyth. " "
5.—A " ; Cornu. " "
6.—A " ; Drawn from photographs with large Rowland grating in Sloane Laboratory. The last three pairs added from measurements of wave lengths. Comparison was made with Higgs' photographs of A which are probably the best yet taken. The drawing shows all details except the "secondary series." The eighteenth pair is cut off.

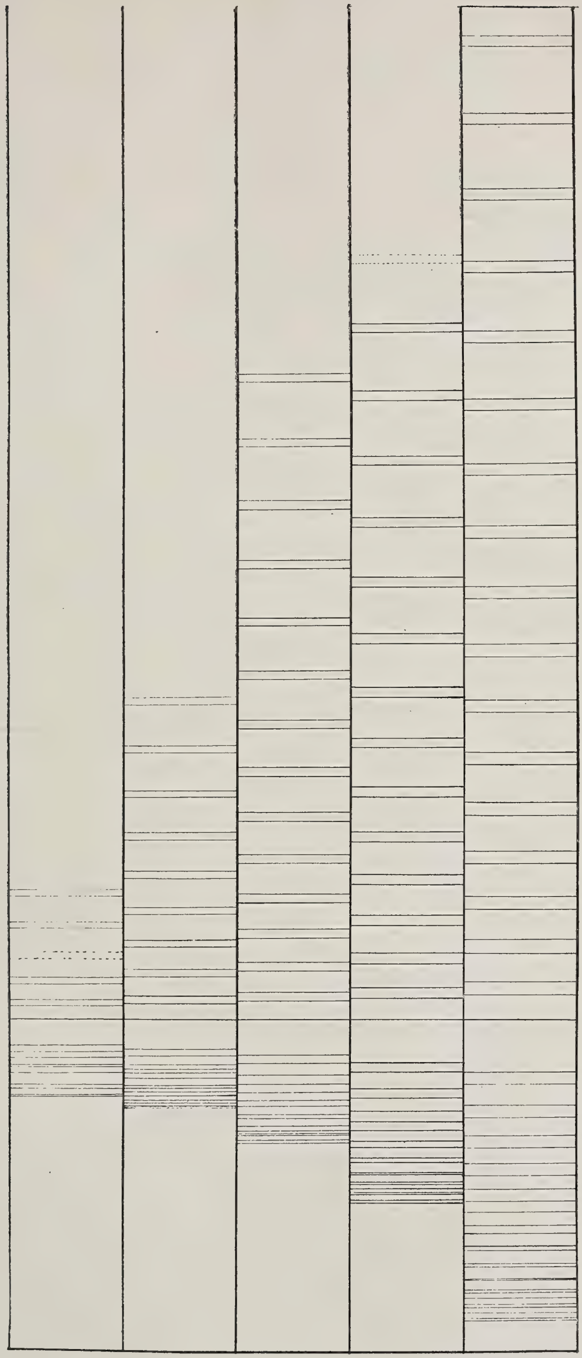
Plate III.

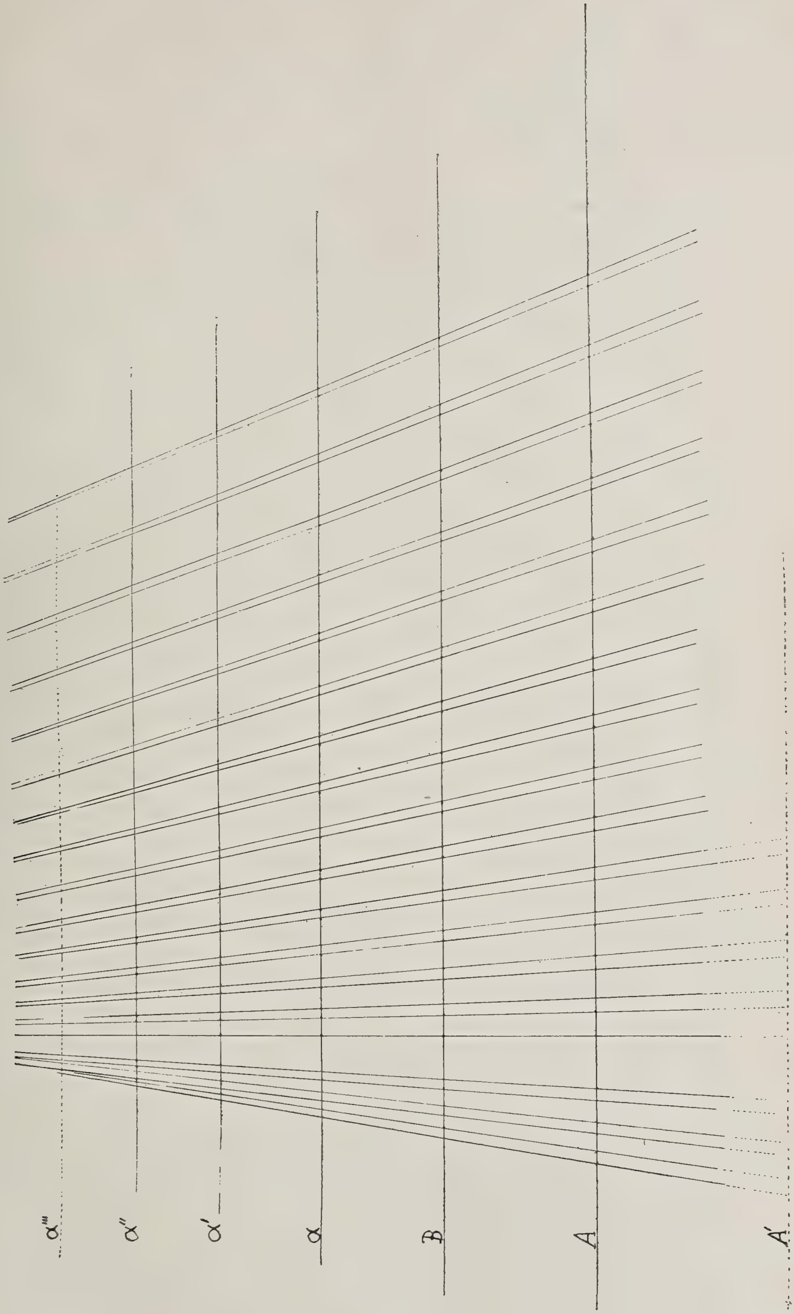
The groups as represented in Plate III are drawn from the measurements of the wave-lengths. Beginning with A, they are arranged in order, one above the other, with the first lines of the second bands forming a straight line. This pyramid-like grouping of the bands is especially effective in showing the symmetrical arrangement of the pairs from group to group and their decreasing width from A to a''.

Plate IV.

The distance between the lines marked A and B is 4^{cm}, representing the distance in wave lengths between these two bands. The other horizontal lines are drawn at distances proportional to their distances in wave lengths from A. Plotted in this way the corresponding lines of the several bands fall almost exactly in a straight line, this being especially true for those lines whose wave lengths are most accurately measured.







α'''
α''
α'
α
B
A
A'

SCIENTIFIC INTELLIGENCE.

I. Geology and Natural History.

1. *United States Geological Survey.*—The following publications have recently been received:

Professional Paper No. 11.—The clays of the United States east of the Mississippi River; by Heinrich Ries. 287 pp., 9 pls., 11 figs. The origin of clay, its composition, varieties and uses is discussed and its geologic distribution described. The greater part of the paper is taken up with a detailed description and discussion of the clay deposits and the clay industry of the states east of the Mississippi.

No. 12.—Geology of the Globe Copper District, Arizona; by F. L. Ransome. 165 pp., 27 pls., 10 figs.

The oldest rocks of the Globe district are crystalline schists of pre-Cambrian age, which, together with intruded masses of granitic rocks, form the core of the Pinal range. Upon these schists lie a series of shales, conglomerates and quartzites, varying in thickness from 500 to 800 feet, which have been assigned to the Cambrian. Overlying these is a series of limestones with a maximum thickness of about 400 feet. They range in age from Devonian to Upper Carboniferous. In addition to the sedimentary rocks there are large masses of diabase, which were intruded chiefly in the form of silts between the sedimentary beds. Later still, another volcanic eruption brought extension masses of dacite into the region.

The structure and topography of the region is largely dependent upon the great number of faults found in the district. Mr. Ransome says, "Probably few equal areas of the earth's surface have been so thoroughly dislocated by an irregular network of normal faults, and at the same time exhibit so clearly the details of the fractioning."

Mining in the district was commenced in 1874. The early work was done on silver and gold deposits, the copper ores which are the predominant ones to-day not having been seriously worked until after 1881. Since then the quadrangle has produced approximately 120,000,000 pounds of copper.

The copper ores belong to two mineralogical classes: (1) oxidized ores being mostly cuprite, malachite or chrysocolla, and (2) sulphide ores being mostly pyrite and chalcopyrite. The first group has furnished the major part of the ore up to the present. The ore bodies exhibit various forms and may be classed as (1) lodes, (2) masses in limestone and (3) irregular mineralization of shattered or permeable rocks. The lodes are usually simple veins occupying fault fissures. The important ore bodies are those in the limestone. These are usually rudely lenticular in shape, and lie roughly parallel to the bedding of the rock occurring scattered irregularly through it. They are usually either in a prom-

inent fault fissure or closely connected with one. Ores of the third class have also contributed largely to the total output.

The ores were undoubtedly originally sulphides deposited by ascending solutions. The igneous rocks of the district probably have had an intimate influence on their formation by supplying material together with heat and chemical activity to the underground waters.

The report closes with a detailed description of some of the more important mines, including maps and sections of the workings. W. E. F.

No. 16.—The Carboniferous Formations and Faunas of Colorado; by GEORGE H. GIRTY. 546 pp., 10 pls. The first 216 pages of this work are devoted to a useful review of the literature and discussion of the interpretations of the geology and paleontology of the Colorado region given by previous writers. In the second part, pp. 217–267, the author discusses the faunal evidence and correlations furnished by the material under investigation; and in the remainder of the volumes (pp. 268–546) the species are described and figured.

The result of study of the collection shows the presence of both Mississippian and Pennsylvanian faunas.

The Mississippian fauna occurs in the Leadville limestone and its equivalents, the Ouray and the Millsap limestones. These are interpreted as equivalent to the Kinderhook and lower Burlington faunas of the Mississippi valley region.

To the Pennsylvanian are referred the Hermosa, Weber, Maroon, Robinson, Molas, and Rico formations. Essentially the same fauna is reported from the Hermosa, Weber, Lower Maroon of the Crested Butte section, and from the Weber shales and grits of the Leadville section. This fauna is considered by the author to be older than any of the Pennsylvanian beds of the Kansas and Nebraska sections. The Rico formation is by its fauna interpreted as probably of about the horizon of the Deer Creek, Hartford and Howard formations of Kansas. H. S. W.

No. 17. Geology and Water Resources of Nebraska West of the One Hundred and Third Meridian; by N. H. DARTON. 66 pp., 43 pls., 23 figs. With a few minor changes this paper is a reprint of pp. 719–785 in the Nineteenth Annual Report.

No. 19.—Contributions to the Geology of Washington. 98 pp., 20 pls., 3 figs. This publication contains two papers: Geology and Physiography of Central Washington; by GEORGE OTIS SMITH, and Physiography and Deformation of the Wenatchee-Chelan District, Cascade Range; by BAILEY WILLIS. During Pliocene time a lowland surface was developed in Central Washington and the ancient controlling drainage system may possibly be indicated. This plain was uplifted and warped so that the Cascade range is complex in type. Geologic processes worked rapidly in this region, as is shown by the Eocene section of 10,000 feet divisible into four distinct formations, separable both by physical breaks and differences in fossil flora. The unique char-

acter of this region is the modification of the peneplain by warping so as to form anticlinal ridges and synclinal valleys. In the Wenatchee-Chelan district glaciation furnishes an additional datum plane and Mr. Willis has worked out the physiography in great detail. He recognizes five physiographic stages from the Pliocene to the Recent, inclusive. As a study of physiographic method and of criteria for recognizing peneplains this paper is a valuable addition to geologic literature.

2. *Alaska, Glaciers and Glaciation;* by G. K. Gilbert, being Vol. III of the Harriman Alaska Expedition reports, published with coöperation of the Washington Academy of Sciences. New York, 1904. (Doubleday, Page & Co.) 231 pp., 18 maps and plates, 106 figs.—This most instructive and suggestive report may be briefly reviewed under four headings: preglacial land forms, erosion by Pleistocene glaciers, existing glaciers, and glacial erosion in general. A noteworthy feature of the preglacial topography was the occurrence of mountain ranges formed by the broad uplift and dissection of extensive peneplains, which, it may be here noted, are but so many additional instances of the difficulty into which Suess's hypothesis of the origin of horsts must lead the geologist. These peneplains and the neighboring ocean were once at (almost) the same level: according to Suess' hypothesis, the peneplains have become horsts, not by local elevation, but by the depression of the surrounding surfaces; and in this case, as in many others where horsts have ancient peneplains for their uplands, it is evident that such an explanation involves the depression of all the oceans of the world, and the continents along with them, the horsts alone standing still. This is of course conceivable, but it is an extravagant conception. Certain parts of the coast show lowlands of denudation adjacent to the mountains, thus recalling the coast plain of Norway as described by Reusch. Gilbert explains the Alaskan coast plain by general erosion when the land had gained something like its present altitude, and does not explicitly call upon marine erosion, as Reusch did for the Norwegian example. Erosion of valleys to a greater depth during a time of greater elevation is also inferred, but hardly proved, unless it is held that glacial erosion cannot have scoured out the channels now occupied by the sea while the land held its present position.

Gannett's thesis that a glaciated valley is comparable with a river channel is supported by a great variety of facts. Cirques and hanging valleys characterize the coastal mountains: repeated examples are figured and described. In this connection reference may be well made to the Chief Mountain (Montana) map sheet, lately issued by the U. S. Geological Survey, an elegant example of fine topographic work by Messrs. Matthes and Sargent, in which cirques and hanging valleys are remarkably well portrayed. Indeed so numerous are the examples of these forms in once-glaciated mountains in many parts of the world that the occasional occurrence of imitative forms in non-glaciated districts can

hardly be used, as they lately have been by Russell (Science, May 20, 1904, 785), to throw doubt on the glacial origin of normal cirques and hanging valleys. It may be difficult to explain the imitative forms, but as the matter now stands, it is their explanation that is deficient, and not the explanation of the normal forms by glacial erosion as stated by Gannett and Gilbert. True, the trunk valleys are often so much deeper than the hanging lateral valleys as to make it very difficult indeed to ascribe their excess of depth to glacial erosion ; yet the hesitation that one may feel here is more likely to be based on a conservative habit of thought than on direct argument ; for the valleys are certainly valleys of erosion, and when it is once shown that glaciers are effective erosive agents, it does not appear more unreasonable to ascribe the great trough valleys to the work of frozen water than to that of molten water. It is pointed out by Gilbert that the main valley sides are relatively smooth and trough-like, sometimes exhibiting details of form that suggest the action of an eroding agent which moved in nearly horizontal lines, and thus contrasting strongly with the ravined valley sides of non-glaciated mountains, where the agent of erosion has manifestly worked on down-slope lines. The extension of these main valleys across the coast plain leads to the conclusion that their erosion was accomplished by the larger glacial streams in consequence of their relatively great velocity ; thus agreeing with the opinion reached by Richter for the over-deepened valleys of the Alps.

The existing glaciers are described and illustrated in much detail, with especial reference to their recent variations. It is shown by a careful comparison of all available descriptions, maps and photographs, that the changes of the glaciers have been singularly discordant during the past century, and the discordance is held to be too great to be explained by lagging. A most ingenious suggestion is then made that under certain changes of mean temperature, one set of glaciers might be caused to advance while others near by would be compelled to retreat. Glacial students who visit Alaska during the present century thus have a pleasing problem set before them for solution.

The volume closes with some general conclusions as to glaciers, in which we find an altogether new view as to the possibilities of glacial erosion beneath the sea. It has been recognized in recent years that the invasion of once-glaciated valleys by the sea was not, as it has usually been regarded, an evidence of submergence, for heavy glaciers can certainly erode beneath sea level. Gilbert now gives reasons for thinking that heavy tidal glaciers are not effectively buoyed up by the water that they enter, and that they erode beneath sea level about as effectively as on a land surface. If this should be fully demonstrated, it would lead to a radical change of opinion regarding the changes of level indicated by fiord coasts. "Plucking" is looked upon as of great importance in glacial erosion. W. M. D.

3. *The Origin and Relationship of the large Mammals of North America and the Caribou;* by Madison Grant, Secretary of the New York Zoological Society.—These articles, reprints from the annual (eighth and seventh) reports of the New York Zoological Society, form an exceedingly interesting volume of about 60 pages, copiously illustrated by 32 exceptionally fine plates, reproductions of photographs of the caribou in their native haunts, in captivity in the N. Y. Z. park, and of mounted specimens in the American Museum. A map showing the distribution of the two kinds in North America is also given. The purpose of the first article, as stated by the author, is "to briefly review the living large mammals of the United States and Canada, and to endeavor to trace their past history," such an analysis being possible because of the increase in knowledge of the true relationship of mammals and their geographical distribution greatly aided by the definite proofs given in recent paleontology. The facts are very clearly presented in concise divisions showing the existence of two definite continental radiations, proved by distinct faunal groupings showing geographical origin and connection, followed by a discussion of the various distinct groups of animals themselves with a table showing their derivation, concluded by a summary of previously mentioned facts. In the second article, the facts correlated in regard to the caribou are presented in a similarly clear manner, showing the origin of the name, classification of the various species with their geographical origin and distribution. K. J. B.

4. *The Mammals of Pennsylvania and New Jersey;* by Samuel N. Rhodes.—This volume (privately published) of 266 pages with 9 plates (reproductions of photographs) and faunal map is, as shown by the title page, a "biographic, historic, and descriptive account of the furred animals of land and sea, both living and extinct, known to have existed in the states of Pennsylvania and New Jersey" and is "designed as both a popular and scientific presentation of a branch of nature-study hitherto unduly neglected." Among the many valuable facts given in the introduction, one of especial interest is that "the list of fossil mammalia found in these two states far exceeds that of the rest of the United States east of the Mississippi river." This is due to the researches of Leidy, Cope, and Marsh among the fossil-bearing limestone caves and fissures in the Delaware valley and in the marl beds of New Jersey. Above 90 species are cited of which 30 are found still existing; these, with over 70 living species and 25 sub-species or geographic races, show not only a surprisingly large mammalian fauna, but also the noteworthy fact that the fossil fauna exceeds that of the living. The vast amount of careful labor expended in compiling this valuable work will be appreciated by all students, and writers on kindred subjects. K. J. B.

5. *Medusæ of the Bahamas;* by Alfred Goldsborough Mayer. Memoirs of Natural Science, vol. I, No. 1, of the Museum of the Brooklyn Institute of Arts and Sciences.—This article of 33 pages, with 7 heliotype plates, is based on observations

made by the author during June and July, 1903. Of the 43 species found, 5 are known only from the Bahamas, 2 of which are locally abundant. Among them, one genus (*Paranemus*) and two species are new to science. The opportunity of studying asexual budding was afforded by a most interesting example of *Eucheilota paradoxica.* The paucity of the medusa-fauna of this locality compared with that of Tortugas, Florida, is given as being largely due to local conditions. The former being situated to the windward, while the latter is to the leeward of the Gulf Stream, is depleted by the prevailing winds, and is poor in those creatures which are mainly dependent upon great currents for their distribution. K. J. B.

II. Miscellaneous Scientific Intelligence.

1. *International Congress of Arts and Science at the Universal Exposition, St. Louis.*—An International Scientific Congress will be held at St. Louis from Sept. 19–25, in connection with the Universal Exposition. Professor Simon Newcomb is the President of the Congress and Professors Hugo Muensterberg and A. W. Small the Vice Presidents. The whole field of knowledge is divided for the purposes of the Congress into seven divisions, these further into twenty-four departments and these finally into some 128 sections. The official program contains the following statements :

"After the opening of the Congress on Monday afternoon, September 19, will follow, on Tuesday forenoon, addresses on main divisions of science and its applications, the general theme being the unification of each of the fields treated. These will be followed by two addresses on each of the twenty-four great departments of knowledge. The theme of one address in each case will be the Fundamental Conceptions and Methods, while the other will set forth the progress during the last century. The preceding addresses will be delivered by Americans, making the work of the first two days the contribution of American scholars. On the third day, with the opening of the sections, the international work will begin. About 128 sectional meetings will be held on the four remaining days of the Congress, at each of which two papers will be read, the theme of one being suggested by the Relations of the special branch treated to other branches ; the other by its Present Problems."

The list of distinguished scholars, from Europe and America, announced as speakers at the Congress, ensures it an eminent degree of success in its grand object of "the unification of knowledge."

2. *Geographen Kalender, 1904–1905,* edited by Hermann Haack ; 290 pp., 16 maps : Gotha (Justus Perthes).—There is no one publication which serves so well the purpose of an annual reference book of geographical matter as Dr. Haack's "Kalender." New explorations, adjustments of boundaries, development of canals, railroads, etc., are described and mapped. To this are added a list of addresses of scientists and societies, a review of the year's geographical literature and a mass of useful statistics.

Obituary.

John Bell Hatcher, Curator of Vertebrate Paleontology in the Carnegie Museum at Pittsburgh, died of typhoid fever at Pittsburgh on July 3, 1904. By his death Paleontology has lost an investigator and writer of unusual ability, a man who had few equals in his chosen line of research.

Born at Cooper, Green County, Iowa, October 11, 1861, his early years were passed among surroundings and under conditions which developed a character of absolute integrity and of rare self-reliance and determination. He entered the Sheffield Scientific School of Yale University in his twentieth year, when he improved to the utmost the educational facilities offered to him. Although a few weeks before the graduation of his class, in 1884, he expressed himself as being still uncertain in his choice of future occupation, it is on record that during his college course he gave especial attention to those studies in Natural History which fitted him for his life's work. Probably Hatcher's marked ability had already become known to the late Professor O. C. Marsh of the Yale University Museum, who secured his services as field collector. Hardly waiting until the close of his graduation exercises, he left New Haven on June 25, 1884, for the West, where he collected in Kansas and Nebraska for about a month, under the direction of Charles H. Sternberg. Later he commenced work by himself, and remained in the field alone until the approach of winter, when he returned to New Haven. When not in the field, much of Hatcher's time was spent in preparing and studying the fossils he had collected, and in making himself generally familiar with them as an aid to further collecting. He also pursued advanced studies in Botany with the late Professor D. C. Eaton, who became sincerely attached to the young scientific worker, and who always expressed the highest regard for his character and ability. In 1885, after collecting Permian fossils in Texas, Hatcher returned to Kansas and continued his work in the Pliocene formations. The seasons of 1886 and 1887, which were spent in the Bad Lands of Dakota and Nebraska, won him renown as a collector. From the famous "Brontotherium Beds," he shipped to the East carload after carload of fossils, including the bones upon which Marsh founded his genera *Brontotherium* and *Protoceras*. In fact, Hatcher's labors in the field were of inestimable value, and the collections made by him, more than those of any other of his scientific assistants, furnished to Professor Marsh the material for his paleontological work.

By this time, Hatcher's services had become so valuable that Marsh kept him constantly in the field. The winter months were spent in Maryland, Virginia and North Carolina. The variegated red and gray clays conspicuous between Baltimore and Washington had long been a puzzle to geologists. Many collectors had visited the outcroppings, but had failed to obtain characteristic fossils at the typical localities. Hatcher, whose

keen eyes were fresh from the western fossil beds, was entrusted with the work. In two months he brought together a collection in which were abundant dinosaurian remains associated with the bones of other reptilian orders.

The summers of 1889 to 1892 were spent in Converse County, Wyoming, where Hatcher obtained a magnificent collection of Ceratopsia material. One of the best known types of this group is Marsh's *Triceratops*, now exhibited in the Yale University Museum. Another notable dinosaur collected by Hatcher is the *Claosaurus*, mounted at Yale by Professor Beecher after Marsh's death. When the latter retired from his position of Vertebrate Paleontologist of the United States Geological Survey, in 1892, funds were no longer available for collecting on so extensive a scale, and Hatcher severed his connection with the Yale Museum. Shortly after, he became Curator of Vertebrate Paleontology and Assistant in Geology at Princeton University. His work during the following years won him the highest praise. In spite of great hardships, he successfully made collecting and exploring expeditions into the wilds of Patagonia. Neither ill health nor accidents, such as the loss of his saddle and pack animals hundreds of miles from any source of supplies, could daunt him, and his work in the southern continent proved not only of the highest value to the naturalist and paleontologist, but his chronicle of these expeditions is also of great interest to the general reader.

In 1900 he accepted the Curatorship of Vertebrate Paleontology in the Carnegie Museum at Pittsburgh, which position he filled with honor to himself and to the great improvement of his department. Engaged by the United States Geological Survey to continue Professor Marsh's work on the Ceratopsia, he had nearly finished that difficult task, involving a careful study of the material at Yale and at the National Museum, which he had himself collected years before. His talent and industry had already won him an enviable position among paleontologists, and he had just accepted the Curatorship of Vertebrate Paleontology in the United States National Museum, when his untimely death occurred.

Hatcher's reputation as a paleontologist rests mainly on his work upon the fossil Reptilia, his principal contributions appearing in the Memoirs of the Carnegie Museum, under the titles of "Diplodocus Marsh," and "Osteology of Haplocanthosaurus." His valuable treatise entitled "Oligocene Canidæ" was published in the same form. Latterly Hatcher developed considerable talent as a stratigrapher, as is shown by his memoir on *Haplocanthosaurus*, the records of the Patagonia Expeditions, and by other shorter publications, which is the more remarkable inasmuch as many able paleontologists have shown little skill in this branch of geology.

Of marked avidity for the hardest work, and of quick and accurate discrimination in his scientific labors, Hatcher accomplished much during his short career. His constant loyalty and thoughtful kindness endeared him to those who were so fortunate as to enjoy his intimate friendship. GEORGE F. EATON.

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Dr. Cyrus Adler,
Librarian U. S. Nat. Museum.

VOL. XVIII. SEPTEMBER, 1904.

Established by BENJAMIN SILLIMAN in 1818.

THE

AMERICAN JOURNAL OF SCIENCE.

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FOURTH SERIES.

VOL. XVIII—[WHOLE NUMBER, CLXVIII.]

No. 105.—SEPTEMBER, 1904.

WITH PLATES V–X.

NEW HAVEN, CONNECTICUT.

1904

THE TUTTLE, MOREHOUSE & TAYLOR CO., PRINTERS, 123 TEMPLE STREET.

Published monthly. Six dollars per year, in advance. $6.40 to countries in the Postal Union. Remittances should be made either by money orders, registered letters, or bank checks (preferably on New York banks).

THE

AMERICAN JOURNAL OF SCIENCE

[FOURTH SERIES.]

Art. XXI.—*The Velocity of the Propagation of Magnetism;* by Henry A. Perkins.

The effect of self-induction in a circuit causing a retardation in the establishment of a magnetic flux is of course well known to everyone; but an allied effect, caused not by the inductance between coil and magnetic circuit, but in the magnetic circuit itself, thus causing a very perceptible interval of time between the appearance of the magnetism at two points, has not been so thoroughly studied, although it must be present in all alternating current machinery to a certain degree. This retardation is thus due to the eddy currents in the core of the magnet in question and is a complicated function of the various physical properties of the core, the frequency and magnitude of the impressed electromotive force.

This phenomenon was first investigated in detail by Oberbech* in 1884. His apparatus consisted in a core with magnetizing coil. Beside this coil were two others whose distance apart could be varied at will. To measure the phase angle between the electromotive force generated in these coils when a sinusoidal e.m.f. was impressed on the main coil, he made use of a dynamometer, the fixed coil being in series with one of the sliding coils, and the movable one with the other. The resulting deflection he showed to be a function of various known quantities and some unknowns that were eliminated by repeating the experiment with added resistance in series with one of the two circuits, thus obtaining a different deflection. This was repeated at different distances up to 20^{cm}. His results show values of the lagging angle from $2° 16'$, when the distance was

* Wied. Ann., xxii, p. 73.

10^{cm} and the core a bundle of 64 small steel wires, up to 96° 12′ in 10^{cm} for a steel bar of $1{\cdot}2^{cm}$ diameter. This shows at least qualitatively what we should expect, that lamination reduces the lag. The curves of flux intensity taken along the bar appeared to be logarithmic curves whose equation was $Q = Q_0 e^{-\beta x}$. β varied somewhat, and his results were tabulated as follows:

$$\beta \text{ for soft iron} = \begin{cases} 10{\cdot}27 \\ 10{\cdot}17 \\ 10{\cdot}07 \end{cases}$$

$$\beta \text{ for hard iron} = \begin{cases} 14{\cdot}8 \end{cases}$$

$$\beta \text{ for steel} = \begin{cases} 14{\cdot}51 \\ 16{\cdot}16 \\ 16{\cdot}37 \end{cases}$$

x being measured in meters. In conclusion, the author says that the size of β varies only as the material and is independent of the diameter. This is also true of direct current phenomena; hence he argues that were it not for the opposition of eddy currents the velocity would be enormous.

When I first began investigations on this effect I was not aware of the work just cited. But inasmuch as the results were somewhat of a qualitative nature, and the method used is open to serious objection, I thought it worth while to continue the research.

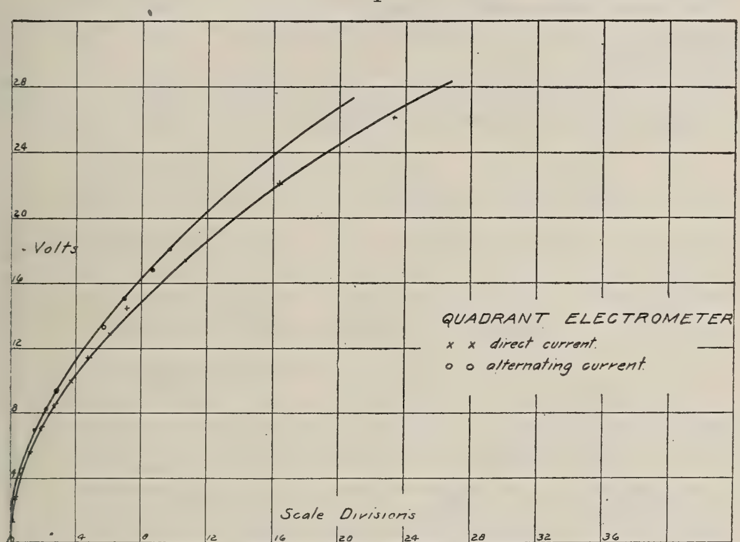
The method employed was in some respects similar to that of Oberbech. A magnetizing coil was mounted on the center of a steel bar about one meter long and having a section of $2{\cdot}83^{cm^2}$. It was of the best English tool steel. This material was used in order to obtain as low a velocity as possible and thus measure it more readily. On the middle of the magnetizing coil were wound 250 turns of fine wire, and sliding on the core were two more coils, one of 500 turns and one of several thousand. As will be seen, the exact number is not an essential quantity.

In performing the experiment one of the movable coils was set at some known distance from the exciting coil at the center, and the angle of lag between it and the small coil of 250 turns was measured. For short distances, up to about 8^{cm}, one of 500 turns was used; beyond that the larger coil. The instrument by which this angle was measured was a small quadrant electrometer having double quadrants and an aluminum needle suspended by a quartz fiber and dipping into sulphuric acid through which the contact was made. The needle and one pair of quadrants constituted one terminal and the other pair of

quadrants the other. By means of two Kempke discharge keys the circuits were so arranged that the electrometer was normally on short circuit, but on pressing the keys simultaneously the terminals of the external circuit were simultaneously attached to the electrometer terminals. This method was essential, for with one terminal free and the other connected to some metal object the instrument would be most violently deflected; hence the necessity for making the contacts exactly together.

As it was purposed to measure alternating voltages, the instrument was calibrated with the use of alternating e.m.f. of the

1



same frequency. These were measured by "weighing" in a Kelvin balance the current that went through a non-inductive resistance across whose terminals the electrometer was connected. The resistance was measured after each reading to allow for possible changes due to heating. It may be of interest to note that the calibration curve as obtained by this method differed considerably from one obtained with constant voltages. This was doubtless due to the capacity introduced by the cup of sulphuric acid into which the needle dipped.

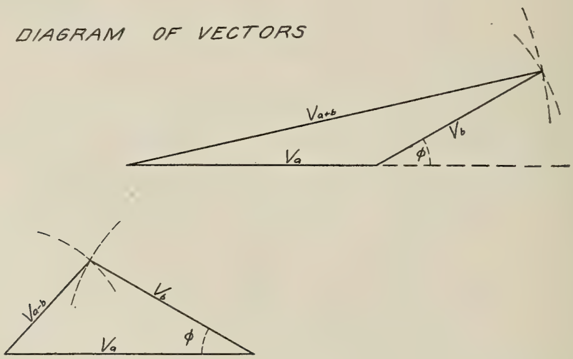
Several readings were necessary in determining a single angle. Calling the small central coil wound on the exciter "A," and the more distant coil "B," we may simplify the description as follows: The electrometer was first connected to A, giving a deflection D_a which corresponded to an induced potential V_a.

Next by connecting to B, D_b and thus V_b was obtained. Then by connecting A and B in series in such a way that they were in accord, V_{a+b}, and finally when opposed $V_{a'-b}$, were observed. The accent above "a" in the last quantity refers to the necessity of reversing the connections of A (or B), and, strangely enough, the deflection given by any coil was slightly altered on reversal. The reason for this I was unable to determine, unless, indeed, it is due to inequalities between the positive and negative loops of the commercial current which was used. This seems unlikely, and I purpose to investigate the matter further. This effect was not harmful if properly observed and allowed for.

With the four readings just referred to it was possible to calculate the angle of lag in two ways that can best be seen in graphic form.

If the two vectors V_a and V_b were in phase, then V_{a+b} must be equal to their arithmetical sum, otherwise it will be less, and

2



this was always found to be the case. The construction can be seen from a glance at the diagram, which gives us ϕ, or the angle of lag. Similarly with the two coils opposed, $V_{a'-b}$ will be greater than the arithmetical difference of $V_{a'}$ and V_b, as shown above. In the results recorded here the latter method was used as being less liable to error, for it involved no large deflection like D_{a+b} and for small values of ϕ it is also true from trigonometrical reasons.

Determinations of ϕ were made at intervals up to nine inches from the central coil, and from these values the velocities for the parts in question were calculated. From inspection of the curve it is clear that $\frac{d\phi}{dx}$ is not a constant, hence the velocity cannot be constant. The velocity at any point in the bar was found from the angle curve by observing the change in lag for a short distance on either side of the point in question. Calling

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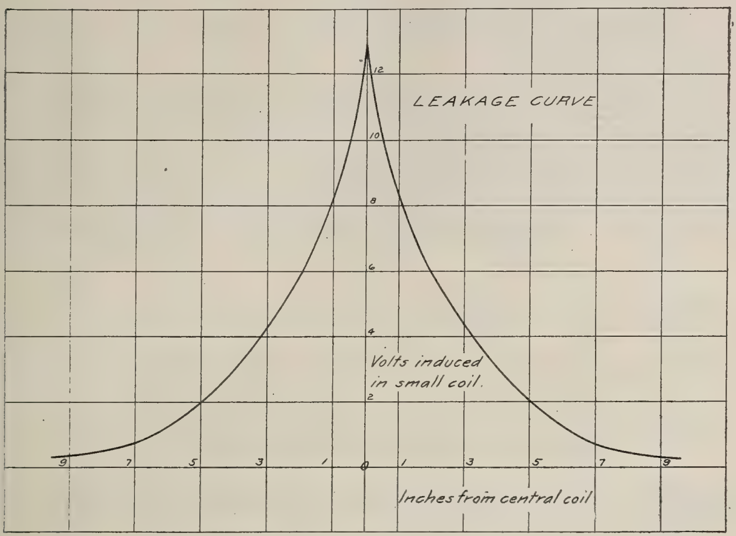
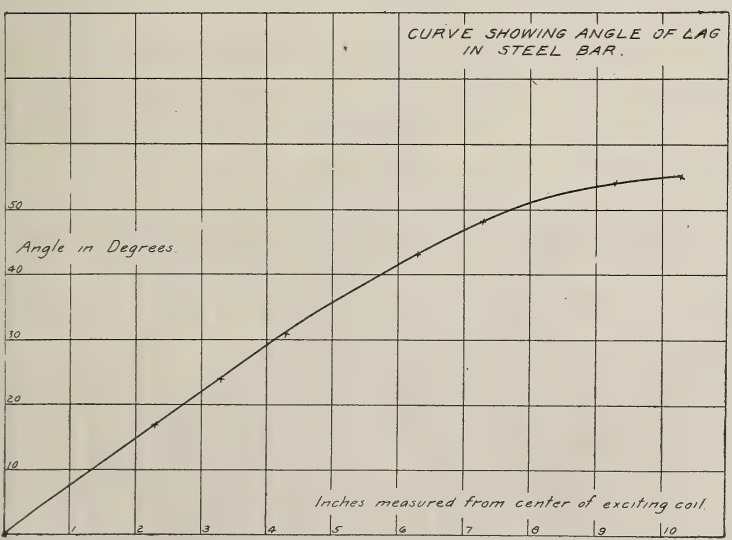

LEAKAGE CURVE
Volts induced in small coil.
Inches from central coil
12
10
8
6
4
2
9
7
5
3
1
0
1
3
5
7
9

4


CURVE SHOWING ANGLE OF LAG IN STEEL BAR.
Angle in Degrees.
50
40
30
20
10
Inches measured from center of exciting coil.
1
2
3
4
5
6
7
8
9
10

this distance "d" and the angular difference "δ," we have $v = \frac{360 \cdot d \cdot n}{\delta}$, where $n =$ the frequency, and in this case was 60 cycles per second.

In comparing the curves of magnetic leakage and velocity it is evident that as the flux in the bar diminishes the velocity increases with a consequent lessening of the lag per unit length. This is what would be expected, for with a decrease of flux the eddy currents must grow smaller, and there is less opposition to the advance of the magnetism. Beyond nine inches the velocity

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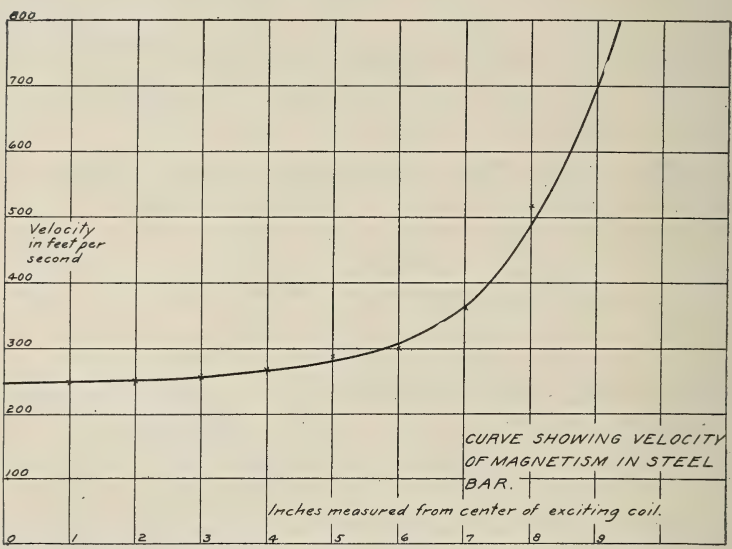


increases with great rapidity and presumably becomes equal to the velocity of light when the flux density is infinitely small, or when the core is a non-conductor. To test this latter case I made an observation with an air core, and with coils A and B about 6 inches apart. In this case the induced e.m.f. was too small to appreciably affect the electrometer, so a very sensitive D'Arsonval ballistic galvanometer was used. Instead of an alternating current a constant voltage was impressed on the exciting coil and the throw of the galvanometer observed at both "make" and "break." Now if B is so adjusted that it gives exactly the same throw as A, then when they are in series and opposed there should be no throw provided the resistance and self-induction of both are made equal. This condition was fulfilled by adding an external coil in series with A, thus mak-

ing that circuit similar to that of B. The result, as expected, was no deflection, although so sensitive was the apparatus that a change of one millimeter in the position of B overthrew the equilibrium. This at least showed that the velocity must be exceedingly great as compared to that in the steel bar.

It only remains to show that the mathematical theory predicts results similar to that observed. In an article by J. Zennech,* the author develops the theory of the propagation of magnetism, which, though it takes no account of hysteresis, should give at least approximate values when properly used. The fundamental equation is similar to that for variable currents:

$$(1) \qquad Qw_m = -\frac{\delta V_m}{\delta x} - p_m \frac{\delta Q}{\delta t},$$

where Q = flux,
w_m = reluctance,
V_m = magnetic potential,
p_m = coefficient of self-induction of the core.

By applying the law that the rate of leakage is proportional to V_m, i. e.

$$(2) \qquad C_m = -\frac{\delta Q}{\delta x}\Big/ V_x,$$

where C_m is the magnetic analogue of capacity, and combining (1) and (2), the equation (3) is obtained:

$$(3) \qquad C_m p_m \frac{\delta Q}{\delta t} + C_m w_m Q = \frac{\delta^2 Q}{\delta x^2},$$

whose solution must be of the form:

$$(4) \qquad Q = Q_o e^{-\beta x} \cdot e^{i(\pi n t - \gamma x)},$$

where β is the damping factor, n = twice the frequency and $\gamma = \frac{\pi n}{v}$, v being the desired velocity. This solution satisfies the equation when

$$\begin{array}{ll} (5) & \left\{ \begin{array}{l} \beta^2 - \gamma^2 = C_m \cdot w_m \\ \text{and } 2\beta\gamma = C_m \cdot \pi n p_m. \end{array} \right. \\ (6) & \end{array}$$

To find v it is necessary to know three of the quantities, β, C_m, w_m and p_m. As p_m presents the greatest difficulty, the first three were selected by the author of this article. β was deter-

* Drude's Ann., 1903, No. 4, p. 845.

mined directly from the leakage curve, assuming it to be fairly well represented by the equation $\beta = \log \frac{Q_o}{Q_x} / x$. The average value was ·16, which gives a curve fitting the original fairly well near its middle point. This agrees quite closely with Oberbech's value for steel; the difference in the position of the decimal point is due to his choice of the meter as the unit of length instead of the centimeter.

The calculation of C_m is more difficult, particularly as Dr. Zennech is not quite explicit in explaining V_x; but I venture to suggest the following method as applied to a point four inches from the center of the exciting coil. The difference of potential of the two faces of a coil of n turns carrying a current I is $\frac{4\pi n I}{10}$ as determined by the amount of work done in carrying a unit pole from one face around outside the coil to the other. This work would be increased if the medium were of greater permeability than air; moreover, the work done would be half the total if the unit pole were carried only from one face to the far end of the bar, where the flux is almost zero. The fall of potential would then vary as Q along the bar. From these considerations I calculated V_x by the following equation:

$$V_x = \frac{4\pi n I}{10} \cdot \mu \cdot \frac{Q_x}{2Q_o} = 27,$$

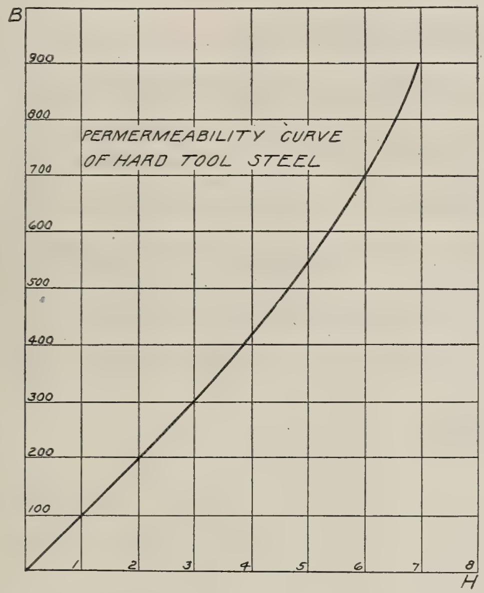
where $n = 4077$ (No. turns in coil),
$I = ·015$ ampères,
$\mu = 2·95$,
and $\frac{Q_x}{Q_o} = \frac{3·1}{12·9}$, as may be seen from the leakage curve.* The value of μ was found by carefully measuring the resistance of the exciting coil and the currents flowing in it under an alternating pressure of 120 volts, when the steel core and an air core were successively used. The impedance in one case was 7998 ohms, in the other 2727. Knowing the resistance and the frequency, it was easy to calculate the coefficient of self-induction for iron (L_i) and for air (L_a), and $\mu = \frac{L_i}{L_a}$.

Referring to equation (2) we still have $\frac{\delta Q}{\delta x}$ to determine, which can be done readily by differentiating $Q = Q_o e^{-\beta x}$ and substituting the values of Q_o, β and x. β has been determined, $x =$

* These and other values were taken from the original curves as plotted in the laboratory. Those prepared for photographic reproduction give the general form correctly but are not strictly accurate copies.

$10{\cdot}16^{cm}$, and Q_o is found from the equation $Q_o = \dfrac{10^8\sqrt{2}E \cdot 2}{\pi n w}$, where $E = 12{\cdot}9$, $n = 500$, $w = 377$, and Q_o is the average value of the flux at the center of the exciting coil. Hence $\dfrac{\delta Q}{\delta x} = -Q_o\beta e^{-\beta x} = -\dfrac{6146 \times {\cdot}16}{e^{1{\cdot}63}} = 193$. Finally $C_m = -\dfrac{\delta Q}{\delta x}\Big/ V_x = \dfrac{193}{27}$, the negative sign vanishing because $\dfrac{\delta Q}{\delta x}$ is negative.

6



The average flux density at a point four inches from the center is 522 lines per square centimeter, obtained similarly to Q_o above, and the permeability at this density was found to be 110, as shown in the permeability curve of the bar used.* This gives the reluctance per unit length as $w_m = \dfrac{1}{110 \times 2{\cdot}83}$; 2·83 being the cross section of the bar.

We are now in a position to make the final calculation, employing equation (5) and solving it for γ, which is equal to $\sqrt{\beta^2 - C_m w_m}$. We have $\gamma = {\cdot}0513$ and $v = \dfrac{\pi n}{\gamma} = 7336^{cm}/_{sec}$ or

* The author owes sincere thanks to Messrs. E. E. Moran and D. H. Miller, students in Yale University, for the determination of the BH curve of the steel bar.

$245^{ft}/_{sec}$ as against $257^{ft}/_{sec}$ actually observed. It must be admitted that values of v calculated for other points along the bar did not agree so closely with observation, those nearer the center being too small and those farther out too large; but considering the fact that equation (5) makes γ exceedingly sensitive to very small errors in the values β, C and w, a closer agreement could hardly be expected.

A more approximate method suggested by Zennech gives $^{\beta}/_{\gamma} = 2{\cdot}4$ for cases of moderate permeability and frequencies of about fifty cycles. Using $\beta = {\cdot}16$ this gives $v = 5712^{cm}/_{sec}$, which is as close as could be expected from the approximate nature of the assumptions.

In conclusion we may, I think, accept as proved that the velocity of magnetism in metallic paths, and especially those of high permeability, is small compared to that in non-conducting bodies. That this effect is due to eddy currents and therefore variable, diminishing as the flux diminishes along the bar. That this velocity is not a simple function of x, but depends on the physical properties of the bar, such as ohmic resistance and permeability, as well as the magnetic density at the point in question. And that this retardation is great enough to cause a very perceptible lag where the density is high and the lamination poor; great enough indeed, it would seem, to call for recognition in the design of many forms of electromagnetic machinery.

Trinity College, July, 1904.

ART. XXII.—*The Geomorphic Origin and Development of the Raised Shore Lines of the St. Lawrence Valley and Great Lakes;* by R. CHALMERS, LL.D., of the Geological Survey of Canada.

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IN a paper published by the writer in 1896 on the "Pleistocene Marine Shore Lines on the South Side of the St. Lawrence Valley,"* and in an official report issued in 1897,† it was shown that the valley referred to and the region of the Great Lakes must have stood at a lower level at the close of the Pleistocene‡ than at the present day, the movements of the ice in the glacial period and the existing altitudes of the shore lines clearly proving this. Investigations regarding the position and elevation of the shore lines of the St. Lawrence basin have been continued at intervals since and considerable new data obtained. Very interesting observations have been made on the north side of the two lower great lakes, Ontario and Erie, showing the geomorphism which the region has undergone in the post-glacial or recent stages of the Post-Tertiary. The following notes, deduced from the field work of the last seven years, are preliminary to a more detailed discussion of the results.

High-level shore lines of marine origin fronting the St. Lawrence to the north have been traced almost without interruption from the Gulf of St. Lawrence westward along the northern base of the Notre Dame Mountains, a distance of 550 miles or more, the altitude of the highest at Gaspe being 240 feet, while as we approach the international boundary east of Lake Champlain it is 865 feet. Another series extends along the north side of the St. Lawrence and Ottawa rivers at approximately the same altitude, reaching 900 feet north of the city of Ottawa. Besides the regional upheaval indicated by the shore lines observed on both sides of the valley, differential vertical movements of a local character have taken place at intervals along these strands since they were at sea level, or in a horizontal attitude; in some places there appears to have been a greater uplift than in others, and such uplift seems occasionally to have been followed by still more local downward movements. On the south side of the valley and in the maritime districts wherever the shore lines rest upon crystalline, or igneous rocks, they were observed to be deformed to a greater extent than elsewhere and raised above the average height. This singular and

* This Journal, April, 1896, vol. i (4th series), pp. 302–308.

† Annual report, Geol. Surv. Can., vol. x, 1897 (new series), pp. 12–54 J.

‡ The term Pleistocene embraces the period beginning with the Post-Tertiary and ending with the Champlain, or with the deposition of the Leda clay and Saxicava sand.

apparently abnormal feature is more particularly noticeable in that portion of the highest shore line which extends along the south side of the valley referred to for a distance of 100 to 120 miles east of the international boundary, where it rests on the northwest flank of the Sutton or Green Mountain range in its extension into Canada. Similar deformations were also observed on the north side of the St. Lawrence and Ottawa valleys, more especially of the latter. On both sides of the St. Lawrence marine plain, however, the shore lines become considerably broken up before approaching the Archean rocks to the west.

In the region of the Great Lakes high-level shore lines were observed and described many years ago by Logan, Chapman, Fleming, R. Bell, Spencer and others, while more recently Lawson and Bell have explored and traced them along the north and northwest side of Lake Superior, where they bounded a great body of water to which the name Lake Warren was given. On the north side of Lakes Erie and Ontario four or more of the strands referred to occur. The lowest, which has been named the "Iroquois beach" by Spencer, and was first traced by him, is not horizontal, but has an average descent southwestward of about two feet to a mile. It extends from the Trent river, or from a point north of Belleville, to the head of Lake Ontario. Another lies above it having a similar slope, not however much more than about a foot to the mile, the altitude falling from 775 feet at Myrtle, Grand Trunk railway, to 705 feet in Lambton county. This is probably a part of the so-called Algonquin shore line, which has been traced on the south side of Georgian Bay with such care and described by Mr. A. F. Hunter of Barrie*. The third is a well-defined one which was followed from Trent river to Hyde Park, Middlesex county, a distance of about 200 miles, and is practically horizontal throughout. The altitude is 890–892 feet. The fourth and highest is terrace-like, and may be called a plateau, as it is 1100 feet high in its eastern extension in Durham county, near Pontypool, and 1200 feet near Stratford, Perth county. A depression crosses it east of the Credit river.†

These four Ontario shore lines are of lacustrine origin; but how the waters of the Great Lakes were held up to their level is the great problem. As stated in the opening sentences of this paper, there seems no doubt that the whole of the region of the Great Lakes stood at a lower level than at the present day during the existence of the earliest and largest of these bodies of water—Lake Warren,—that is, at the period when the shore lines now found at an altitude of 1100–1200 feet were

* Summary Report, Geol. Surv. Can. for 1902, pp. 279–302.

† The altitudes were all measured from railway stations and referred to mean sea level. See Summary Report, Geol. Surv. Can., 1902, pp. 272–274.

formed. A great mass of literature bearing on the origin and development of these old water lines and of the lake basins themselves has appeared from time to time in the scientific journals during the last two or three decades, and geologists are by no means in accord as to their origin. In the United States the hypothesis of an ice dam in the St. Lawrence Valley during the latter part of the glacial period is generally accepted, but most of the Canadian geologists are inclined to regard that of an oscillating land barrier to the north and northeast of the Great Lakes as the most probable cause.

In regard to the latter theory it may be stated that there is a belt of granite or Archean rocks about fifty miles wide crossing the St. Lawrence at the Thousand Islands connected with the Adirondacks to the south, and with the great Archean area to the northwest, towards which it widens out as we proceed in that direction. This Archæan neck, as it is sometimes called, seems to have been an oscillating axis in the Post-Tertiary period and up to the present day. As, however, the shore lines of the St. Lawrence Valley and Great Lakes are of post-glacial age, it is only its later Pleistocene and recent history with which we are concerned. At this stage the St. Lawrence Valley below the Thousand Islands and the region of the Great Lakes would be at a lower level than at present, as already stated, and the axis referred to must have been higher. This valley would then be a gulf or arm of the larger Gulf of St. Lawrence and the barrier described would form, on its east side, the shore of the Champlain sea, and on its west a great fresh-water lake, or series of lakes, would be held in, the floor of which is now represented to some extent in Southwestern Ontario by plains and terraces 1100–1200 feet above the sea. These water levels, as already pointed out, can be seen at Stratford and on the watershed between Ontario and Simcoe Lakes, also at corresponding heights in the Lake Superior basin, as described by Bell and Lawson.*

The sequence of events which occurred in the St. Lawrence Valley and basin of the Great Lakes brought about by the changes of level which followed may be thus summarized:—

1. A subsidence of the Archean rocks immediately to the north of the Great Lakes with correlative upward movements to the east and to the west. These changes of level seem to have reached a stationary position, temporarily, when in the lake region the 890–892 feet shore line was formed; and in the St. Lawrence Valley, the 890–895 feet terrace.

2. Another subsidence of the axis referred to then followed,

* The Geological History of Lake Superior; Trans. Can. Institute, Memorial volume, 1849-99, by Dr. R. Bell; Sketch of the Coastal Topography of the North Side of Lake Superior, by Dr. A. C. Lawson.

with apparently the same correlative uplifts to the east and to the west, when on reaching the level of the 775–705 feet shore line in the basin of the Great Lakes there was another halt. This shore line is also recorded in the St. Lawrence Valley, though now shown at various altitudes and in various positions. The two higher strands north of Ontario and Erie Lakes then became slightly tilted towards the northeast.

3. Another downward movement of the central axis following, the formation of the "Iroquois beach" took place on the one hand, and corresponding shore lines at low levels in the St. Lawrence Valley on the other. The upper shore lines, both on the east and west of the central oscillating axis, would now slope towards it, though they have since returned nearly to a horizontal attitude.

4. Following was a period of moderate oscillations along the axis referred to, some downward and some upward, the forces producing them having apparently been largely spent, or having approached an equilibrium. These changes resulted in the breaking down of the strands along the margin of the oscillating zone on both sides, and in a considerable amount of denudation taking place. Lake Ontario was probably lower than at present, perhaps nearly or quite at sea level.

5. A slow series of reverse movements then set in which consisted mainly in a rise of the crystalline axis. This has continued to the present day with correlative subsidences in the areas formerly uplifted to the east and west. These changes are evidenced by the fact that the "Iroquois beach," which was, just previous to this period, in a horizontal attitude, is now tilted to the southwest, and similar movements, though in a reverse direction, have taken place in the St. Lawrence Valley, the raised shore lines there now sloping eastward longitudinally. What the amount of the uplift at the Thousand Islands has been since, it is difficult to say. Judging from the present levels of the "Iroquois beach" it would seem as if the rise must be fully 200 feet; but the hinge or axis of the movement may not have been at the eastern end of the existing beach.

The oscillatory movements of the barrier referred to would seem to have been limited and slow, nevertheless they affected, it appears, not only the granite axis, but a wide tract of country on either side, beyond which, as shown, complementary movements occurred. Even when the axis was at its lowest level, however, Lake Ontario must have been somewhat higher than the sea or gulf; for there is evidence of an eastward flow of the lake waters at this stage. Stratified beds of gravel and sand showing deposition in waters flowing in the direction indicated were found upon the granite axis at altitudes of 800

to 850 feet, or 300 to 400 feet higher than similar deposits on either side; and yellow sands and gravels containing concretions, common in the basins of Ontario and Erie lakes, were observed in the marine area to the east overlying the Saxicava sands and Leda clay, which must also have been carried down by an overflow of the lake waters.

The discussion of the causes of these oscillatory and complementary movements will have to be reserved for the present. It may be remarked, however, that it is only reasonable to assume that in the folding and compression of the rocks of the Northeast Appalachians along the border of the large Archean area to the north, there must necessarily have been transverse thrusts and uplifts along certain lines of weakness, though most of these have hitherto been supposed to antedate the post-Tertiary period. Three of these apparently crossed the St. Lawrence basin,—one at the Thousand Islands, a second along the line of igneous intrusions crossing the St. Lawrence Valley at Montreal, and a third at Quebec city.

The foregoing explanation of the phenomena is offered tentatively, though the writer has observed all the facts in the field and feels confident that it is to geomorphic changes we shall have to look for a solution of the problems presented in regard to the elevated strands and the origin of the basins of the Great Lakes themselves. The theory, it will be seen, includes only one downward movement with three or four pauses or temporary cessations of the stresses producing them, and one upward movement, still in progress, the latter proved to some extent by observations made by Professor G. K. Gilbert of the United States Geological Survey.* The geomorphism which has taken place outside of the St. Lawrence basin is not considered in this note; it is thought, nevertheless, that the changes there will all harmonize with those outlined in this paper. It seems to the writer that the theory is a more rational one, and more in accordance with observed geological phenomena, than that of glacial dams. The author is convinced that when the history of the great changes of level which have occurred in the region in question during the post-Tertiary period comes to be studied more in detail, geomorphology will be found to constitute an important factor, and along with denudation, enable us to explain the conformation of the surface features without resort to such adventitious and epigene agencies as are sometimes employed.

Ottawa, Canada, June 22d, 1904.

* Recent Earth Movements in the Great Lakes Region, Eighteenth Annual Report, U. S. Geological Survey, 1896–7, part ii, pp. 601–647.

ART. XXIII.—*The Material and Shape of the Rotating Cathode*; by H. E. MEDWAY.

[Contributions from the Kent Chemical Laboratory of Yale University—CXXX.]

IN a previous article from this laboratory* a method has been described for the rapid, electrolytic precipitation of metals upon a rotating platinum crucible made to serve as a cathode. In the present paper is given the record of experiments with other and cheaper metals, used in place of the more expensive platinum, as well as cathodes in the form of discs.

Experiments were made with a silver crucible of 50^{cm^3} capacity, carefully cleaned, dried at 100° C., weighed and adjusted to the rubber stopper which serves to hold the crucible and press against its inner wall two platinum strips which make the electrical connection.

Into the electrolytic cell was put an acidulated solution of copper sulphate, standardized by deposition of copper upon the rotating crucible of platinum.

Deposition upon Silver.

	Copper taken. grm.	Copper found. grm.	Error. grm.	Current. Amp.	N. D. 100.	Time. min.
(1)	0·1088	0·1086	−0·0002	2·	6·6	15
(2)	0·1088	0·1090	+0·0002	2·	6·6	15
(3)	0·1088	0·1084	−0·0004	1·5	5·	15
(4)	0·1088	0·1085	−0·0003	2·	6·6	15
(5)	0·1088	0·1080	−0·0008	2·	6·6	15
(6)	0·1041	0·1041	+0·0000	2·	6·6	15
(7)	0·1041	0·1046	+0·0005	2·	6·6	15
(8)	0·1041	0·1039	−0·0002	2·	6·6	15

The results of these experiments would seem to indicate that the use of a silver crucible leaves little to be desired so far as accuracy is concerned.

To remove the copper from the crucible, the deposit was rubbed off as much as possible and the rest dissolved in a strong boiling solution of hydrochloric acid, and this was accomplished with but trifling loss of silver, as is shown in the statement below:

	I.	II.
Weight of crucible before treatment	36·0089	36·0062
Weight of crucible after treatment	36·0062	36·0041
Loss of silver	0·0027	0·0021

* Gooch and Medway: This Journal, xv, 320, 1903.

Since the crucible should in any event be weighed before each determination, such small loss does not seriously affect the availability of the silver crucible as a substitute for platinum.

Similar experiments were made with a nickel crucible of 50^{cm^3} capacity, under a procedure exactly the same as that described, with the results as recorded.

Deposition upon Nickel.

	Copper taken. grm.	Copper found. grm.	Error. grm.	Current. Amp.	N. D. ·100.	Time. Min.
(1)	0·1041	0·1028	−0·0013	1·5	5·	15
(2)	0·1041	0·1054	+0·0013	2·	6·6	12
(3)	0·1041	0·1036	−0·0005	2·	6·6	15

These results show that while nickel may be employed as a cathode, too much reliance must not be placed upon results obtained by its use when the greatest exactness is required. Care must also be taken in drying the crucible, since nickel is very easily oxidized with a consequent increase in weight. The deposit of copper was removed from the crucible with nitric acid, with considerable loss of nickel, as the following will show:

	I.	II.	III.
Weight of nickel crucible before treatment	17·6478	17·6161	17·6091
Weight of nickel crucible after treatment	17·6161	17·6091	17·5932
Loss of nickel	0·0317	0·0070	0·0059

So it appears that, while the silver crucible may with some economy and without sacrifice of accuracy be substituted for the platinum crucible used as a rotating cathode in the electrolytic determination of copper, the ease with which the crucible of nickel is attacked, both during the analytical process and in the subsequent removal of the deposit, is a bar to the use of that metal for the rotating cathode.

Shepherd* recommends the use of the ordinary disc anode of platinum as the rotating cathode, in place of the platinum crucible, while a stiff platinum wire, carried in semi-circular conformity to the edge of the disc cathode, serves as the anode.

According to my experience with this form and adjustment of apparatus, the deposits obtained are not so adherent as might be desired and tend to crumble away from the edge of the disc; and the same thing is true of discs of copper and silver. The probable reason for failure to obtain an adherent

*Jour. Phys. Chem., vii, 508, 1903.

deposit is that the edge of the disc, being nearer the anode, receives more current and larger deposit of copper than the central portions, with the consequence that the deposit upon the edge, built out and fragile, tends to break off under the rapid rotation of the disc. To remedy this defect, I have used for an anode a strip of platinum extending across the cell under and parallel to the rotating disc, so that the current may be equalized all over the disc. With the apparatus arranged in this manner, the following very good results were obtained in the precipitation of copper.

Deposition upon the Platinum Disc.

	Copper taken. grm.	Copper found. grm.	Error. grm.	Current. Amp.	N. D. 100.	Time. min.
(1)	0·0670	0·0672	+0·0002	2·	12	15
(2)	0·0670	0·0668	−0·0002	2·	12	15
(3)	0·0670	0·0666	−0·0004	2·	12	15
(4)	0·0670	0·0671	+0·0001	2·5	15	15
(5)	0·0670	0·0670	±0·0000	2·	12	15

The attempt to substitute aluminum for platinum, though the former metal has been recommended by Hough,* as material to receive the deposit, was not successful, owing probably to the film of aluminum oxide always present. Various measures were taken to remove this film—e. g., the aluminum was treated with hydrochloric acid and quickly transferred to the solution, a few drops of hydrofluoric acid added before the current was passed—but all to no avail, the copper falling off as fast as deposited.

From my experience, it seems that the disc is inferior to the crucible for use as a rotating cathode. Not only does the disc fail to hold the deposited copper as well as the crucible, but there are difficulties of manipulation which render the drying and weighing of the deposit upon the disc comparatively inexact.

* Jour. Am. Chem. Soc., xx, 302.

ART. XXIV.—*Structure of the Upper Cretaceous Turtles of New Jersey: Lytoloma;** by G. R. WIELAND. (With Plates V–VIII.)

IN 1865 Leidy described as *Chelone sopita* certain chelonian marginals from the Upper Cretaceous or Greensand of Tinton Falls, Monmouth county, and several others from Mullica Hill, Gloucester county, New Jersey. One of these specimens, including three left marginals and part of a fourth, was figured as the type.†

In 1870 Cope established his genus *Lytoloma*, at the same time making a not very clear reference of Leidy's *Chelone sopita* to both *Propleura* and *Lytoloma*.‡ The type species of the latter genus, *L. angusta*, as figured, is seen to consist of a single marginal and fragmentary lower jaw with a remarkably long symphysis. Bearing in mind, however, the closely associated manner in which the numerous forms from the New Jersey Greensand occur, there is at present no positive proof that this marginal and lower jaw belong to the same individual or even species, although both these possibilities are probable.

The close resemblance of the lower jaw of *Lytoloma* to that of *Chelone crassicostatum* (Owen, 1849)§ was noted by Cope. The latter type consists of a skull and lower jaw articulated in normal position, and is a rarely perfect specimen. It was more completely freed from its matrix,—a hard septarian nodule from the London Clay (Lower Eocene), and further illustrated and described, by Lydekker, in 1889, as *Lytoloma crassicostatum*.‖ Its generic relationship to *L. angusta* of the New Jersey Greensand, and to the lower jaw from the Landenien (inférieur) of Erquellinnes, Belgium, first described by Dollo as *Pachyrynchus*,¶ and later referred to Euclastes,** appears to be unquestioned.

* The first paper of this series, on *Adocus, Osteopygis*, and *Propleura*, was published in this Journal, Feb., 1904. The third paper will be on *Agomphus*.

† Cretaceous Reptiles of the United States, Smithsonian Contr. to Knowl., vol. xiv, 1865, pl. xix, fig. 5.

‡ Extinct Batrachia, Reptilia and Aves of North America, 1869, pp. 140, 145; and pl. xi, figs. 1–1b.

§ Fossil Reptilia of the London Clay, Part I. Chelonia, Paleontographical Society, p. 27, pl. xi.

‖ On a skull of the Chelonian genus *Lytoloma*. Proc. Zool. Soc., London, 1889, pls. vi, vii.

¶ Les Cheloniens, Landeniens (Eocène inférieur) de la Belgique, Bull. Musée Roy. d'Hist. Nat. de Belg., t. iv, No. 3, Juill, 1886.

** With reference to the priority and synonymy of the species here discussed, it is necessary to note that the skull *Euclastes platyops* Cope was first mentioned in 1867; hence *Euclastes* antedates *Lytoloma* two years. Moreover, according to Dollo (Sur le Genre *Euclastes*, Ann. Soc. Geol. du Nord., t. xv, p. 114, Mars, 1888) *Euclastes* includes *Chelone* Owen, 1841; *Lytoloma* Cope, 1871; *Glossochelys* Seeley, 1871; *Puppigerus* Cope, 1871; *Pachyrynchus* Dollo, 1886; *Erquellinesia* Dollo, 1887. But later Boulenger and Lydekker (Geol. Mag., Dec. 3, vol. iv, p. 270, 1887), pointed out that *Euclastes* is preoccupied; thus the later name *Lytoloma* becomes valid.

It is thus seen that the cranial characters of *Lytoloma angusta* Cope are inferentially known and point conclusively to a position in the Cheloninæ, although as yet no adequate description of a Lytoloman carapace from the Greensand of New Jersey has been given. It is therefore of distinct interest to find that the Yale specimen No. 625 proves to be a fairly complete carapace, with marginals so distinctly like those of *L. angusta* as to indicate their specific identity. Moreover, the rather close relationship to *Propleura*, and the various primitive characters present, add to our knowledge of the early marine forms, and bring us a step nearer to the actual lines of descent of existing marine turtles from littoral forms. While not known to have survived beyond the Eocene, the Lytolomas show by their structure that they were not more than generically removed from the existing genus *Chelone*. Before passing on to the description of the carapace, however, it will, because of the extended synonymy just reviewed, the considerable number of years since the collection of the materials from New Jersey, and the fragmentary condition of many of the specimens, be necessary to note briefly the evidence as to accompanying cranial characters.

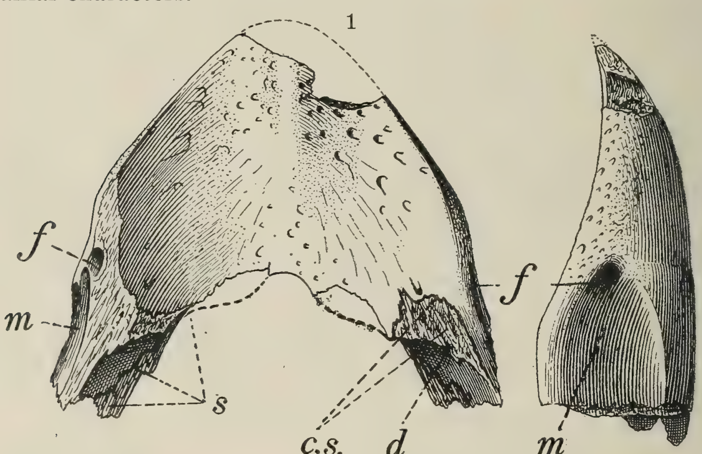

FIGURE 1.—*Lytoloma angusta* Cope. Superior and lateral view of Dentalium. ×$\frac{4}{5}$. (Y. S. 913, from Upper Cretaceous Greensand of Hornerstown, New Jersey. *c. s.*, coronoid suture and sutural surface; *s*, splenial suture and sutural surface; *d*, dental foramen (orifice slightly arched over); *f*, nutrition foramen (for mandibular branch of jugular vein—Bojanus); *m*, masseteric fossa (insertion of masseter muscle).

The Lower Jaw.

Evidence of the specific association of lower jaws and marginals of the *Lytoloma angusta* form is not abundant in the Yale collections, though fairly conclusive. A dentalium which is accompanied by a fragmentary but characteristic marginal is

shown in figure 1. Several more or less isolated jaws of the same form attain about double the size of that illustrated.

The relative width of the lower jaw of *Lytoloma* is much greater than in the living Chelonians. Its further peculiarities are mainly to be observed in the dentalium, notable for its remarkably long symphysis and very large pits for the insertion of powerful masseter muscles. These specialized features primarily suggest a *conchifragous habit.** The massive imperforate palatal surface described below also strongly supports the view that these Lytolomas had become littoral conch-eaters, finding their home and an abundant supply of mussels and other "shell fish" on the New Jersey Cretaceous shore lines.

The Cranium.

With the exception of *L.* (Euclastes) *platyops* Cope no further *Lytoloma* crania from the Upper Cretaceous of New Jersey have been figured. The only specimen in the Yale collection referable to the genus is an isolated anterior portion of a skull, which is, however, in a wonderful state of preservation, as shown in the accompanying text—figure 2 (A, B, and C). There is no means of now determining with certainty whether or not this specimen is a *Lytoloma angusta.* It is quite possible that the lower jaw pertaining to it had a somewhat differently shaped coronoid region than that of *L. angusta.* Rather than erect a new species on such slender evidence, it may suffice to refer to this rare and interesting specimen by number when comparing its characters with those of other forms. With *L. platyops* Cope† this comparison is as follows:—

Lytoloma (Euclastes) *platyops* Cope.	*Lytoloma,* Yale specimen No. 913a.
1. "Maxillaries and palatines separated throughout by the prolonged vomer."	1. Maxillaries and palatines *probably* separated throughout by elongate vomer.
2. "Posterior nares opposite palatal front margin of orbits" (? ?).	2. Internal narial opening well back from both the lower (palatal) and the upper (orbital) anterior border of the palatines.
3. "Premaxillary margin projecting beak-like;" alveolar face little concave.	3. As in *L. platyops;* that is, premaxillaries projecting more than in the Chelonidæ, but not forming a projecting and decurved beak as in either *Chelydra* or *Archelon.*
4. "Vomer forming a central ridge."	4. Outer (or palatal) surface of vomer flat anteriorly but raised between the palatines.
5. Floor of nasal meatus perforate for hook of mandible.	5. *Floor of nasal meatus imperforate and very thick.*
6. "Nostrils superior behind the short projecting beak (not borne on a projecting muzzle)."	6. As in *L. Platyops* (not *Bothremys*).

* Dollo, Première Note sur les Cheloniens landeniens (éocène inférieur) de la Belgique, Bull. Musée Roy. d'Hist. Nat. de Belg., t. iv, No. 3, p. 138, 1886.

† Loc. cit., p. 148.

In both the above skulls (borrowing further from the description of *L. platyops*, as given by Cope), the descending portion of the prefrontal is very wide, and equal to the width of the maxillary outside the small lachrymal foramen. Inter-

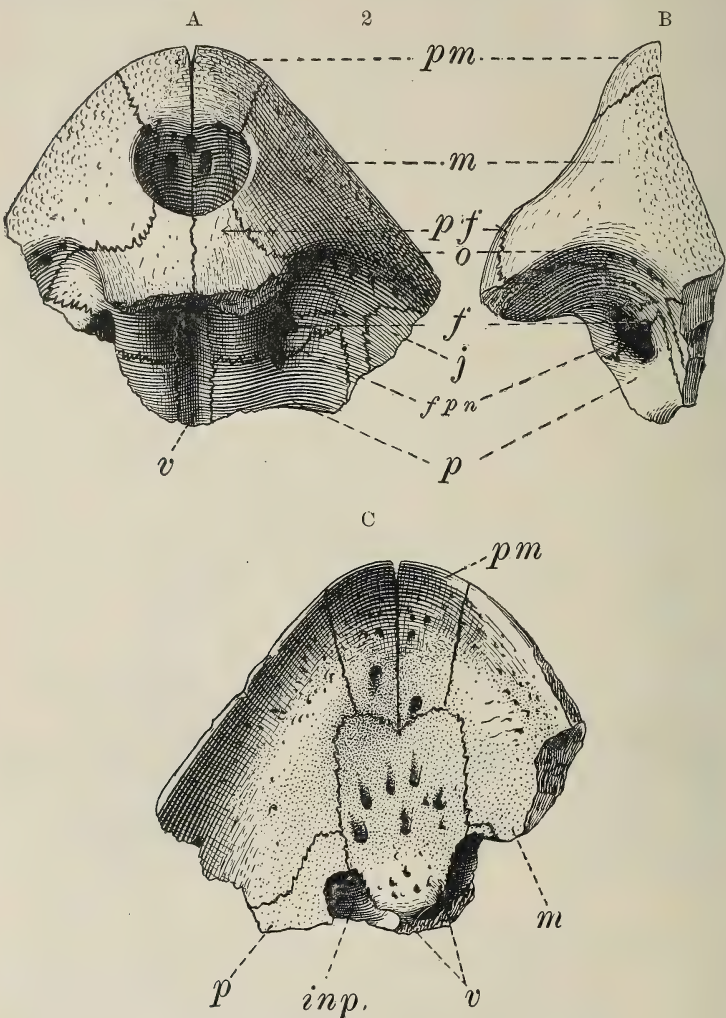

FIGURE 2.—*Lytoloma angusta* ? Anterior portion of cranium. × $\frac{4}{5}$. Yale specimen 913a. From the Upper Cretaceous of Hornerstown, New Jersey.

A, superior,—B, right lateral,—C, palatal view.—*pm*, premaxillary; *m*, maxillary; *pf*, prefrontal; *o*, anterior border of orbit; *f*, foramen (*alveolare superius* ? ?); *fpn*, *foramen palatino nasal;* *j*, jugal; *p*, palatine; *v*, vomer; *inp*, internal narial passage (the vomero-palatine wall being partly broken away).

nally the columns of the prefrontals converge below nearly to an acute angle and are directed forward, also much backward in *Lytoloma* (Yale specimen No. 913a), thus forming a strong internal base on the vomer. They restrict the nasal meatus, leaving its diameter less than that of the columns.

The internal nares in the present specimen open far back; but the long, broad, and massive vomer is fairly complete, and it is not likely that the palatines closed in behind it to further roof the narial passage. If so, herein may lie a marked difference from the still more specialized Eocene Lytolomas from the London Clay and the Landenien inférieur of Belgium. In describing the skull of *Lytoloma crassicostatum* Owen, Lydekker says: "one of the first points which strikes the observer [on comparison with *Thalassochelys*] is its extreme shortness, the width at the widest part of the temporal arch being exactly equal to the length from the occipital condyle to the muzzle; whereas in the Loggerhead the former diameter is considerably less than the latter, whilst in *Chelone* the difference between the two diameters is still greater. Still more noticeable is the backward position of the posterior nares, which are situated at a point one third the distance from the condyle to the muzzle, as indeed is mentioned in M. Dollo's description of the Belgian specimens. In that description it is, however, stated that the boundary of the posterior nares is formed by the development of the palatal plates from the pterygoids. So far, however, as can be seen from the present specimen, it would appear that this border is really constituted by the palatines, since on either side there seems to be a distinct suture separating the bones forming the border of the posterior nares from the undoubted pterygoids. Looking at the arrangement of the palatines in the Loggerhead, it would seem much more natural that these should be prolonged backwards, rather than that the pterygoids should assume the condition assigned to them by M. Dollo. In either case the vomer is excluded from the posterior nares, but its position anteriorly is not shown in this specimen." (It is obscured by the lower jaw which is in place.)*

The Carapace and Plastron.

The specimen (Yale Catalogue, No. 625) on which the following description is mainly based was received from the West Jersey Marl Company, May 1, 1869. It is from the old, long unworked marl pit, one and one-half miles east of the village of Barnsboro, Gloucester county, New Jersey. Willows, holly, pine, etc., now grow scatteringly over this area of former excavation some thirty acres in extent, which has yielded so many other interesting fossils, among them the remarkably fine carapace and plastron *Osteopygis Gibbi.*

* Lydekker, loc. cit.

The recovered portions of the present specimen, shown in detail by the stippled areas in Plate VIII, consist of (*a*) the third, fifth and sixth neurals; (*b*) the antero- and postero-pygal; (*c*) the pleuralia of the right side less the free-rib tips, but with the inner or neural borders of all but the second distinct; (*d*) the first to the fifth pleurals inclusive of the left side, the free-rib tips of the second and fifth being present, also a fragment of the seventh pleural, as indicated by its form and the postero-lateral furrow of the fourth vertebral horn-shield which crosses it; (*e*) the fourth to the seventh inclusive, and the ninth marginals of the right side, and the fourth to the eleventh marginals inclusive of the left side, with the anterior half of the pygal marginal. There are also some fragments of the accompanying plastron, which, although too incomplete to permit the exact restoration of any of the plastral elements, indicate a plastral form even more reduced than, but otherwise much like that seen in *Osteopygis* and *Propleura*.

With the exceptions mentioned, all parts of the carapace, as far as recovered, are uncrushed and but little broken. As sent to the museum, they were dissociated, but the sutures are well preserved and almost without exception interlock in their normal position, so that it is possible to determine these elements, as well as the general form of the carapace. The fortunate presence of the third neural, with both the adjoining third pleurals as well as two rib tips of the left side, leaves no doubt as to the width of the carapace. Moreover, the borders of the missing second, fourth, seventh, eighth, and ninth neurals are indicated exactly, and those of the first neural approximately. The anterior sutural border of the first left pleural being complete, there can be little doubt but that the nuchal had approximately the outline indicated in Plates VI–VIII. The length of the missing three anterior marginals can only be inferred, but must be nearly that shown in outline.

With regard to the general form of the marginals and of the posterior neurals in the present genus, and in *Osteopygis* and *Propleura*, figures 3–6 in the text afford data for exact comparison. Taken in conjunction with the facts already given, they require little further description. It may only be noted that the specimen represented in figure 5 shows a diminution of the posterior neurals more marked than that in *Osteopygis Gibbi*, while the condition in *Propleura*, figure 6, is more like that of the present form.

As indicated in Plates VI and VII, the horn-shield furrows are all distinct and rather broad. The carapace is of suborbicular outline, being broadest across the posterior end of the fifth neural. In this respect it is somewhat intermediate between cordate forms like those of the existing Cheloninæ

and the Osteopyges, which are broadest across the anterior end of the sixth neural. In the present more primitive turtle the cordate form of the Chelonine carapace is beginning to appear, the swinging back of the eighth rib into a pit of the eleventh marginal, and the consequent leaving of the tenth

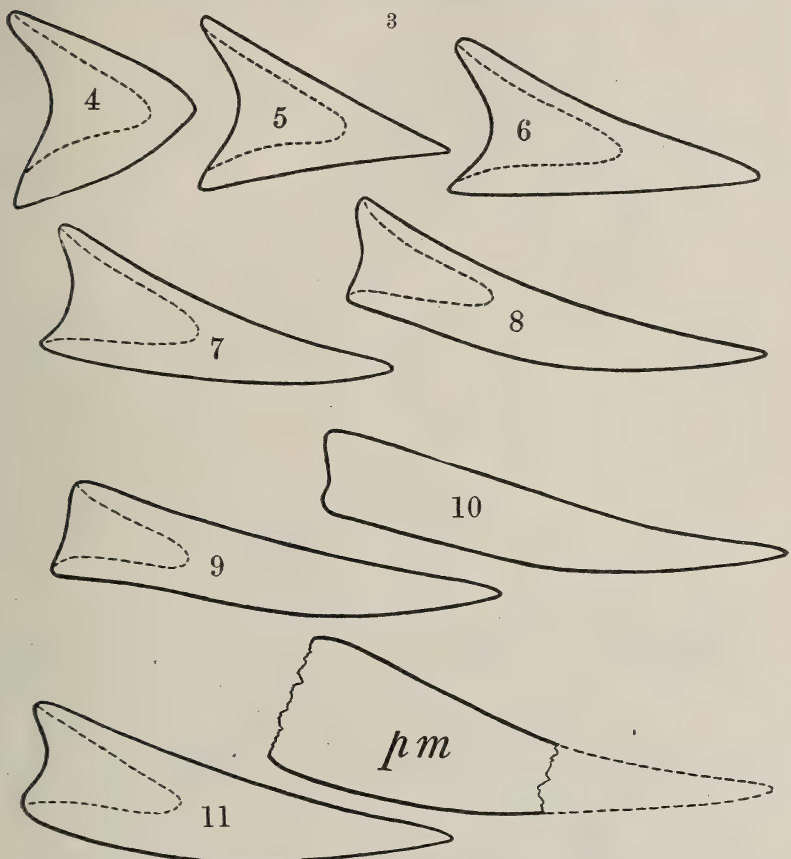

FIGURE 3.—*Lytoloma angusta* Cope (Yale specimen 625). Natural size. Vertical middle transverse section through the 4–11, and pygal (*p m*) marginals. Respective rib pits in dotted outline.

marginal without a supporting rib, as in *Chelone*, having already occurred. Compare plates V and VI. In *Osteopygis Gibbi* the femur is longer than the humerus, and from general comparison it may be argued that in the present species of *Lytoloma* the femur is relatively shorter than in *Osteopygis*, but not so shortened as in the existing marine turtles. This intermediate development is an important point.

In addition to the fragmentary portions present, the general form of the *plastron* is in part indicated by the marginals. The digitations of the antero-external limb of the hyoplastron projected into several small shallow pits in the lower border of the posterior half of the fourth and the anterior half to three-fourths of the fifth marginals, thus forming a dactylate junction

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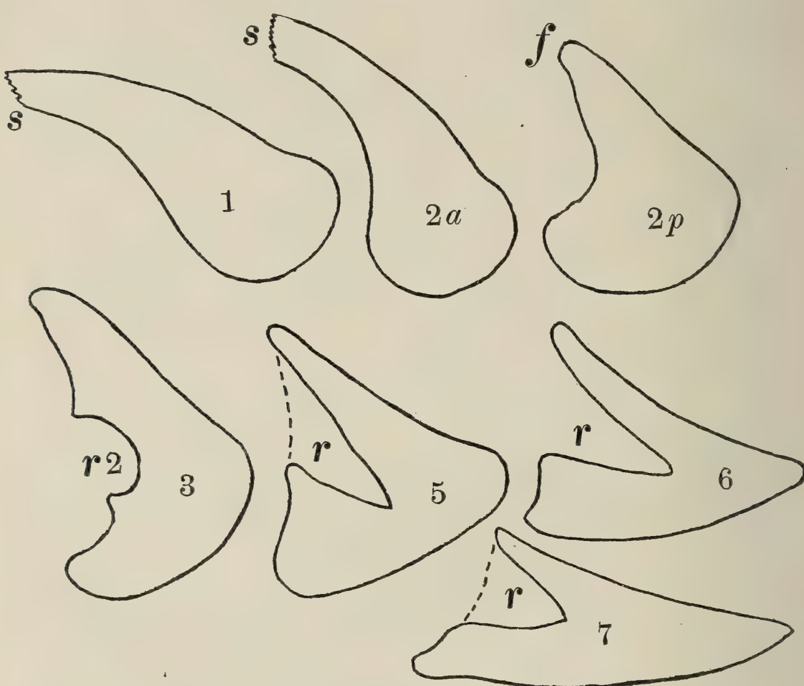


FIGURE 4.—*Propleura borealis* Wieland (type). $\times \frac{2}{3}$. Vertical, middle, or end transverse sections of marginals for comparison with the marginals of *Lytoloma* shown in figure 3.

1, 3, 5, 6, 7, middle sections numbered respectively; 2*a*, 2*p*, anterior and posterior end outline (or section) of second marginal; *s*, *s*, inner border of first and second marginal (uniting by suture to first pleural and not free as in *Lytoloma*); *f*, free border; *r*2, claw-shaped furrow in third marginal for reception of second rib; *r*, *r*, *r*, rib pits in 5–7 marginals for reception of respective, *i. e.* 3–5 ribs.

6·5 to 8^{cm} in length. This is a distinctly shorter junction than in *Osteopygis*, in which the outer hyoplastral limb extends forward to the second marginal, and is about equal in extent to that seen in *Eretmochelys*. No distinct pits for the reception of the outer digitations of the hypoplastron exist in the fossil at hand. In the Osteopyges, these are present for both limbs of

the plastron, marginals 2 and 8 being deeply pitted for the extreme ends of the hyo- and hypoplastron, respectively, as explained in the description of *O. Gibbi* and *Propleura*. In

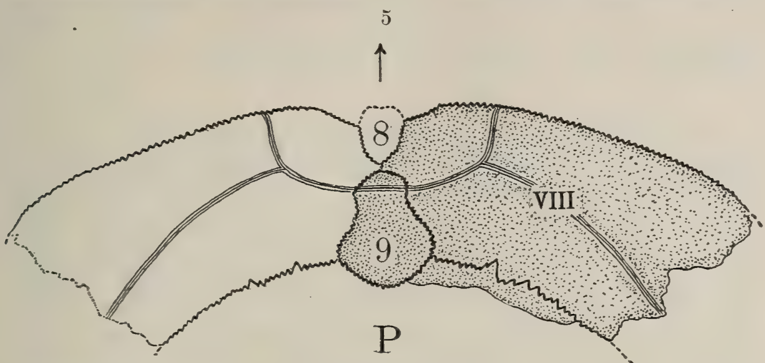


FIGURE 5.—*Osteopygis* sp. (Yale specimen 908). × ½. Right eighth pleural with the ninth neural and a portion of the antero-pygal (P) attached. Horn-shield borders of fourth and fifth vertebralia and fourth costal horn-shields distinct and shown in triple line. (Thickness of neural is ·7 cm.)

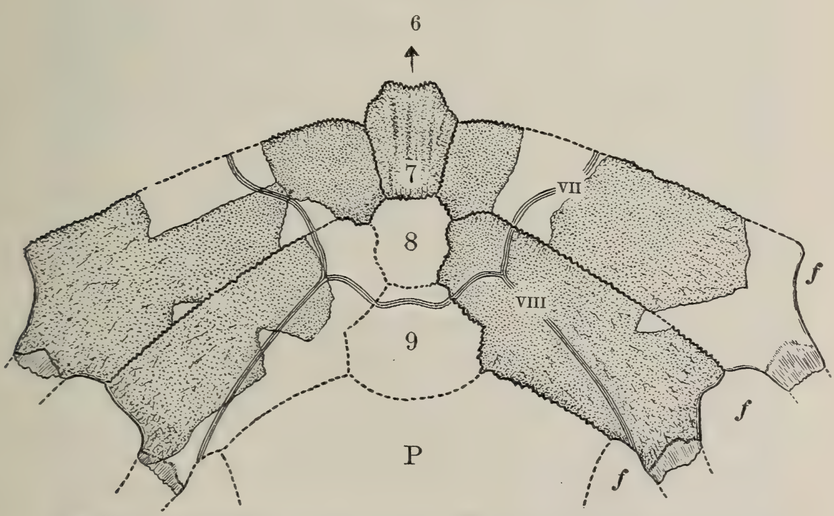


FIGURE 6.—*Propleura* sp. (Yale specimen 559). × ⅛. Right and left seventh and eighth pleuralia and seventh neural with borders of the fourth and fifth vertebral and the fourth costal horn-shields distinct and shown in triple line. Stippled portions only preserved. 7–9, neuralia; VII, VIII, pleuralia; P, antero-pygal; *f*, *f*, *f*, the three posterior pleuro-marginal fontanelles. (Thickness of pleuralia at sutural edge ·3–·5 cm.) Barnsboro, New Jersey.

the living Cheloninæ, the marginal pits for the plastral digitations are indistinct. Hence, *Lytoloma* is also intermediate in this respect.

Adocus, *Osteopygis*, *Lytoloma*, and *Chelone* thus *virtually* form a series passing from a strong cleido- to a weak dactylo-sternal plastral junction. The large anterior and posterior plastral foramina and the elongated entoplastron, however, are distinct departures from such a plastron as that of *Adocus*, leading to the plastral form seen in living sea turtles.

Synopsis of the Characters of Lytoloma.

Cranium.—Agreeing in most characters with the existing Cheloninæ, but specialized for a conchifragous habit; short, very broad, with external nares directed as much upward as forward. Vomer large and heavy; internal nares roofed over back of vomer by union of palatines in Eocene species (Lydekker and Dollo), but probably not in New Jersey Upper Cretaceous forms; palatal surface perforate for lower jaw in *L.* (*Euclastes*) *platyops* Cope, heavy and imperforate in *Lytoloma* (Yale specimen No. 913a = *L. angusta?*).

Lower Jaw.—Short and broad, with a very long symphysis, and wide and deep lateral pits for the attachment of heavy masseters.

Carapace.—Suborbicular in outline, with wide and persistent pleuro-marginal fontanelles; composed of 51 bony plates with the boundaries of the (38) horn-shields distinct, the numerical agreement thus being complete in *Osteopygis*, *Propleura*, and *Chelone.* Marginals 11 pairs, narrow anteriorly, but increasing in breadth to the eleventh, which is nearly as broad as long, with outer borders forming an evenly continuous curve to the eighth marginal, beyond which the carapace is more and more emarginate at the ends of the marginals, upper and nether surfaces of equal area, inner surface a shallow rounded furrow; both outer surfaces of fourth marginal nearly flat, with slight concavity of the upper surface and convexity of the lower surface beginning with the fifth and increasing to the eleventh, supported by rib tips only, and upper inner borders bounding the series of large pleuro-marginal fontanelles; rib pits deep and of round to elliptical section, those for the second to the eighth ribs being borne posteriorly on the third to ninth marginals inclusive, the tenth marginal ribless and the eleventh supporting the ninth rib anteriorly, as in *Chelone.* Nuchal large and broad. Neuralia (9) without marked tendency to the suppression of any of the final members of the series, as in *Adocus* and *Osteopygis.* Antero- and postero-pygal as in *Chelone;* surface of the plates smooth, not pitted, and as in the living Chelonians.

Horn-shields.—(38 in number) agreeing numerically with those of *Chelone.* Vertebralia broader than long.

Plastron.—Much as in *Osteopygis*, but with a narrower

bridge (as indicated by fragmentary portions accompanying Yale specimen No. 625, and by marginals 4 and 5).

Limbs.—Little known; humerus and femur thalassoid, and of nearly equal development.

Habitat.—Infralittoral. *Habit.*—Conchifragous.

Range.—Upper Cretaceous and Lower Eocene of Europe and America.

*Systematic Position of Lytoloma and of Osteopygis.**

Where shall we place *Lytoloma*, which in common with *Osteopygis* and *Propleura* has a reduced and somewhat *Chelydra-* or *Staurotypus*-like plastron, and a distinctly *Chelone*-like carapace? It is my belief, based on certain somewhat fragmentary fossils which it is proposed to illustrate later, that in the New Jersey Upper Cretaceous there were already present forms more nearly related to *Chelone* than is *Lytoloma*, although as Dollo well suggests such are far rarer than has been assumed. Second, the free tenth marginal of *Lytoloma* indicates that the swinging back of the ninth rib (or eighth and ninth ribs), thus leaving the ninth or tenth marginal, as the case may be, without rib-support, took place early, and was correlated with the shortening of the femur and the development of heavy front flippers. Third, it appears that *Osteopygis* and *Propleura* belong to a side line, with long and still chelic femora, which never accomplished the rib change just mentioned and did not survive; and fourth, *Lytoloma* originally sprung from this side line. If so, the latter genus developed by parallelism a carapace which, with the skull (that of *Osteopygis* being yet unknown) and the thalassoid humerus, brings it so near to *Chelone* as to make necessary the inclusion of both these genera in the same subfamily.

Having settled this point, the question remains as to whether the two genetic groups containing *Osteopygis*, *Propleura*, and *Lytoloma* on the one hand, and the living members of the Cheloninæ and their more direct ancestors in the other, shall be included in the same subfamily. *Osteopygis*, the most primitive of all the forms in question, is removed from *Chelone* by its less modified limb structure, with all or nearly all the claws present; by its less reduced marginals, consecutively rib-

* In my first paper on the Upper Cretaceous Turtles of New Jersey (this Journal, vol. xvii, Feb., 1904), the opinion was tentatively expressed that *Osteopygis* and *Propleura* might best be separated in a distinct family, namely Cope's Propleuridæ, but the utmost degree of separation any one might suggest, now that *Lytoloma* has been more closely considered, would be as a subfamily,—the Propleurinæ. The position now assigned to these forms is virtually that given them in a provisional classification of marine turtles, proposed earlier (this Journal, vol. xiv, p. 108, 1902), and to which I shall as yet adhere, although recognizing with Dollo the great difficulty, if not impracticability, of satisfactorily dividing the Cheloniidæ into subfamilies in the present imperfect state of our knowledge of the group.

supported; by the absence of pleuro-marginal fontanelles and the nether articular process of the nuchal, and finally by its mere *Chelydra*-like pelvis and earlier type of plastron. Doubtless there are also cranial differences. There is, therefore, between *Osteopygis* and *Chelone*, when considered alone, a very distinct structural interim such as might well characterize two subfamilies. *Lytoloma*, however, is so exactly intermediate that taken with other forms, existing and extinct, there exists a nearly continuous morphological series, passing by simple generic or even lesser stages from the most specialized existing Cheloninæ back to *Osteopygis*. In fact the greatest hiatus remaining unbridged appears to be the ribless ninth or tenth marginal, as seen in *Lytoloma* and existing forms. I am at a loss to surmise if this condition was due to a slowly effected change, or was suddenly developed after the appearance of pleuro-marginal fontanelles in the early line, giving rise to the two genetic groups mentioned. In either case it must have been, as already hinted, correlated with femoral shortening and the development of strong front flippers, and is scarcely to be considered as of more than generic value. If a separation into two subfamilies were made, it would have to be based mainly on this feature, as furnishing the only sharp distinction.

The final conclusion must be that *Osteopygis* and *Propleura* can be placed in a separate subfamily, the Propleurinæ, on genetic grounds, but that further discovery may bring them very near if not into the Cheloninæ. Moreover, as has been seen, these forms, though not apparently forming a closed series, permit the statement that *Osteopygis* was no more than generically separated from some strongly web-footed littoral turtle, which was the true ancestor of the existing Cheloninæ.

The facts given in the present and preceding papers on the Upper Cretaceous turtles of New Jersey, as well as in my paper on *Toxochelys*, indicate the manner in which the marine turtles have been derived from generalized land forms, together with their line of descent. Aside from the carpal and tarsal changes involved and as yet but meagerly illustrated by fossil forms, the most interesting future discoveries will be the ancestral, littoral, and fluviatile Osteopygoid tortoises.

Measurements of Lytoloma.

(A) The dentalium of *Lytoloma angusta* (Yale specimen No. 913.) Uncrushed.

Width (measured from outer extremities of the coronoids)	7·5 cm
Distance (on median line) of hook from anterior ends of the coronoids	4·7
Length of median symphysis	4·2
Greatest vertical depth of median symphysis	1·1

(B) Anterior portion of the skull of *Lytoloma* sp. (Yale specimen No. 913 a = *L. angusta* ?.) Uncrushed.

Length of palatal surface of vomer	3·3
Width " " "	2·0
Length of palatal surface of premaxillary	2·7
Greatest width of palatal surface of premaxillary	1·0
Greatest thickness of vomeral partition between the nares	1·1

(C) The carapace of *Lytoloma angusta.* (Elements uncrushed and disarticulated. Yale specimen No. 625.)

Length (estimated to within one or two centimeters)	58·
Breadth (greatest, as measured across anterior end of fifth neural)	53·

(1) *Bony Plates.*

	(a) Exact length on outer edge of carapace.	(b) Width along groove of horn-shields.	(c) Greatest thickness.
Nuchal	--	--	--
1st marginal	--	--	--
2d "	--	--	--
3d "	--	--	--
4th "	5·5	2·5	2·4
5th "	7·2	3 6	2·3
6th "	7·2	4·3	2·2
7th "	8·	4·8	1·8
8th "	8·	5·6	1·5
9th "	8·2	6·	1·3
10th "	7·5	6·	1·3
11th "	7·8	5·5	1·5
Pygal "	4·7	(5·5)	1·8

	Length on median line.	Greatest width.	Thickness.
Nuchal	----	----	--
1st neural	(5·0)	(4·0)	--
2d "	(5·0)	(5·0)	--
3d "	4·4	4·4	·6
4th "	(5·5)	(4·2)	--
5th "	4·1	4·1	·7
6th "	4·1	3·4	·7
7th "	(3·1)	(3·3)	--
8th "	(3·0)	(2·7)	--
9th "	(3·5)	(3·0)	--
Antero-pygal	3·7	8·0	1·1
Postero-pygal	6·0	(8·0)	--
Marginalo- "	6·0	4·7	1·8

	Length over curvature.	Median width.
1st pleural	20·	5·
2d "	24·	6·
3d "	25·	5·5
4th "	25·5	5·3
5th "	24·5	5·
6th "	22·	5·
7th "	19·	5·5
8th "	15·	5·

(The large pleuro-marginal fontanelles are approximately one-third the length of the pleurals which respectively bound them.)

(2) *Horn-shields.*

	Length on median line of carapace.	Greatest breadth.
Nuchal	----	----
1st vertebral	----	11·
2d "	10·	14·5
3d "	11·	13·5
4th "	11·4	15·
5th "	----	----

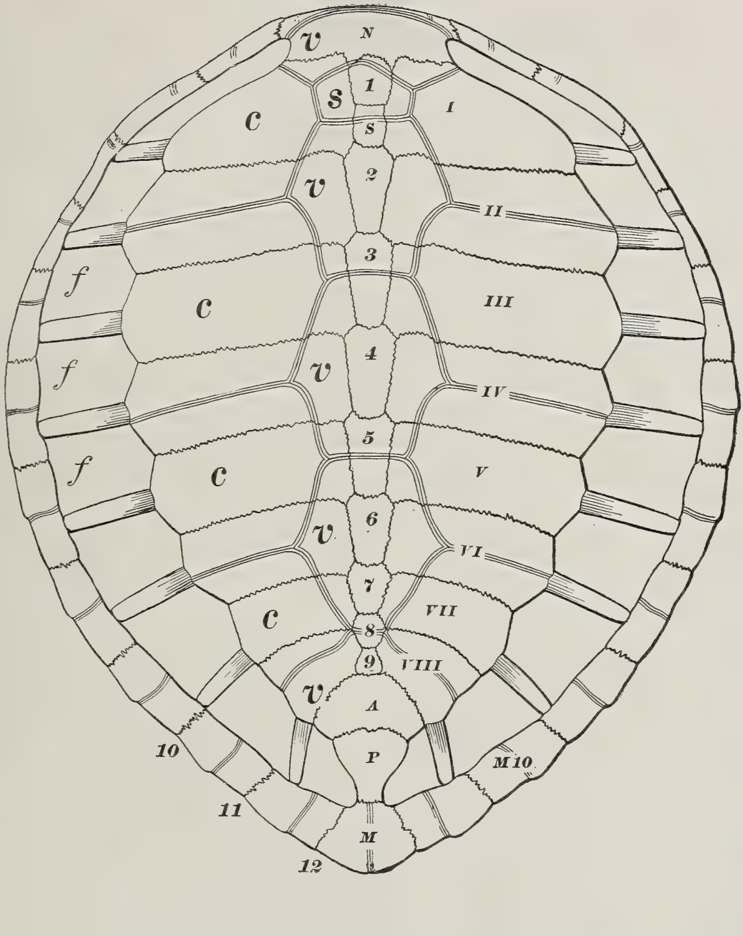
Length of fifth–eleventh marginal horn-shields, respectively, measured along outer border of carapace :—6·5, 7·5, 8·0, 8·5, 8·0, 8·0, 7·5.

LETTERING OF PLATES V–VIII.

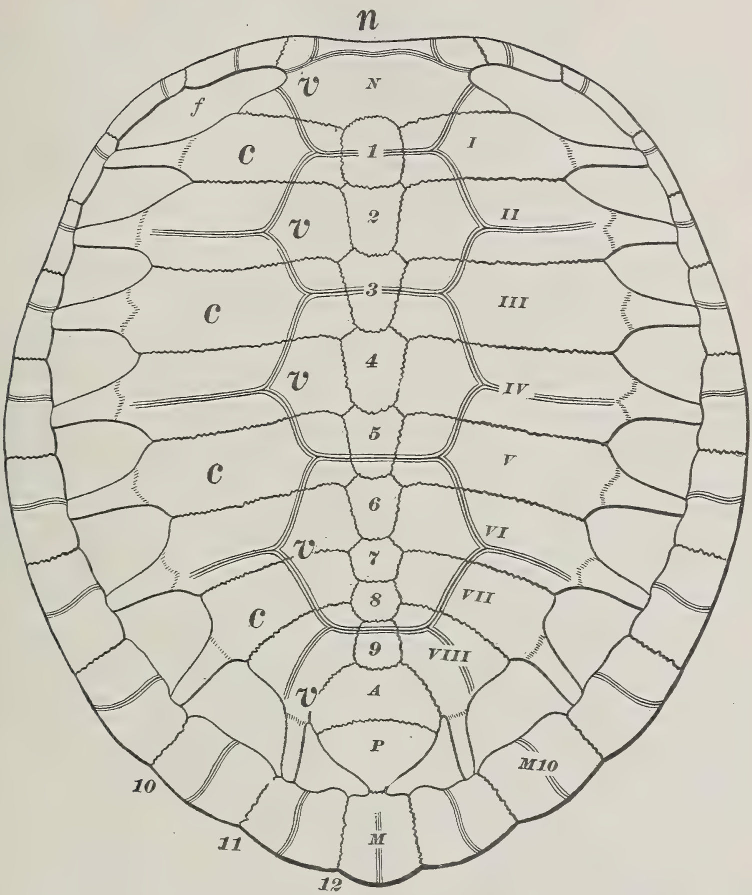
(a) Bone Plates :—*N*, Nuchal ; *1–9*, Neuralia ; *A*, Antero-, *P*, Postero-, *M*, Marginal-Pygal ; *I–VIII*, Pleuralia ; *M9–M11*, 9th–11th Marginals ; *s* (in Plate V), Supernumerary neural.

(b) Horn Shields :—*n*, Nuchal ; *v, v, v, v, v*, 1st–5th Vertebralia ; *c, c, c, c*, 1st–4th Costalia ; *S* (in Plate V), Supernumerary vertebral ; 10–12, Marginalia ; *f, f, f*, Pleuro-marginal fontanelles.

Yale University Museum,
New Haven, Conn.

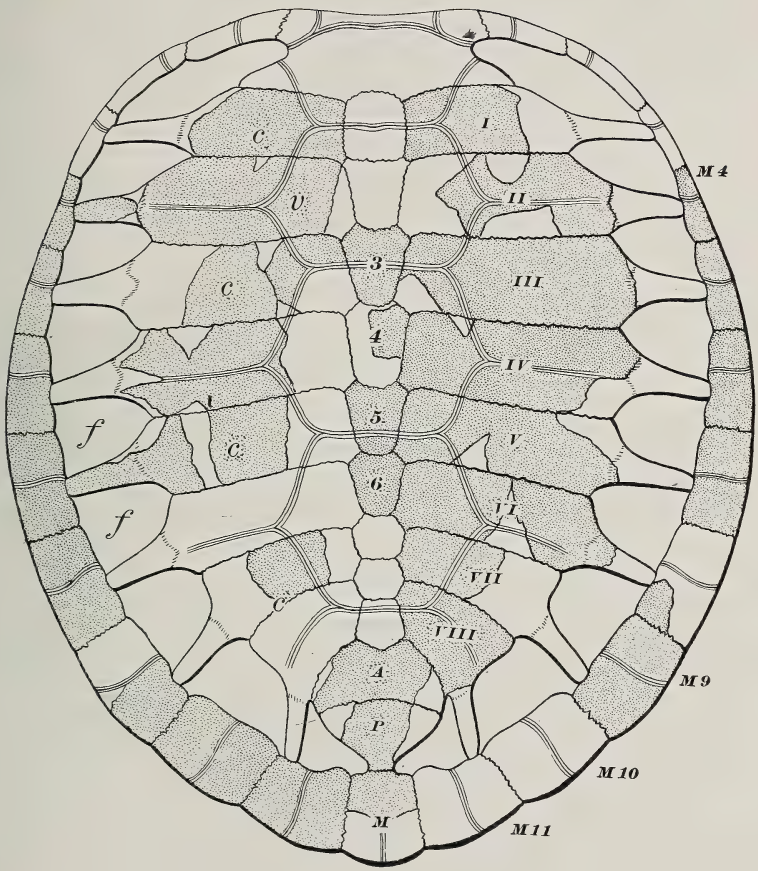


Carapace of *Chelone mydas* L. (var. or sp. nov.) Southern Atlantic coast of the United States. A young specimen ×¼. Free borders in smooth, sutures in zigzag, and boundaries of the horn-shields in triple line.



Carapace of *Lytoloma angusta*. × about $\frac{1}{5}$. Drawn from the specimen shown in the following Plate, VII.

Carapace of *Lytoloma angusta* from the Upper Cretaceous Greensand of Barnsboro, Gloucester Co., New Jersey, as partly restored and mounted in the Yale Museum.—See Plate VIII.
Actual length of Carapace about 58 cm.



Carapace of *Lytoloma angusta*. × about $\frac{1}{5}$. Diagrammatic figure. The stippled surfaces show the parts of the original specimen as recovered in a disarticulated and more or less broken condition. See Plates VI and VII.

ART. XXV.—*The root-structure of North American terrestrial Orchideæ;* by THEO. HOLM. (With figures in the text.)

FEW orders have offered a larger number of interesting data in the various phases of the life-history of plants than the *Orchideæ.* By their manifold structures, readily perceivable among their various biological types, they have for years attracted considerable attention and furnished ample material to writers on morphological and anatomical botany. It is quite natural that the epiphytic species have received a more general treatment than the terrestrial, on account of their unquestionable prominence in floral and vegetative characters, besides that their cultivation being less difficult has made them more accessible to study than the others. Among the terrestrial species very few have been studied from a general point of view except old-world species, but several of these have, nevertheless, served as the very basis of such magnificent contributions to science as those of Irmisch. While, thus, our native, terrestrial *Orchideæ* are very little known from a morphological and anatomical point of view, the following notes on their root-structure are offered as a small contribution to the knowledge of these interesting plants, with the intention to add some further observations in a subsequent paper, which we have made upon the other organs.

As a general result of these observations we might state here, that it seems to be a rule that a tuberous rhizome is only provided with slender roots as is the case with *Arethusa*, *Calypso*, *Bletia*, *Tipularia*, *Aplectrum*, etc., while species with slender rhizome may possess tuberous roots, as for instance: *Orchis spectabilis*, *Platanthera*, *Spiranthes*, etc., or the roots may be equally slender, as in *Cypripedium*, *Goodyera* and certain species of *Pogonia: verticillata*, *ophioglossoides* and *divaricata.*—We might, also, call attention to the fact, that the development of such varied structures of roots and rhizomes does not seem to be dependent upon any special nature of environment; on the contrary, species with tuberous rhizomes may occur in open bogs as well as in deep, shaded woods; and species with tuberous or slender roots may be found in bogs, ravines, in dry fields or in clearings in thickets. In this particular respect the plants themselves seem to possess a very pronounced individuality, and are difficult to classify as meso-, hydro- or xero-phytes. It appears even to be rather uncertain whether some of these species are to be considered as auto-phytes or hemisapro-phytes.—And when we consider the general structure of the roots alone, it seems quite

impossible to offer any satisfactory explanation as to certain facts, for instance, the presence of a velamen in *Tipularia discolor*, and its absence in *Aplectrum*, although the nature of the surroundings, the substrate even, is the same in both, and they both are terrestrial. In *Bletia verecunda*, on the other hand, the development of a similar velamen may be explained as an inherited character, since other species of the genus are epiphytic. A similar approach to the epiphytic root-type as demonstrated by certain species of *Spiranthes* is, also, very puzzling, inasmuch as this genus does not, otherwise, exhibit any analogies in common with epiphytes.

From these data, it may be readily appreciated that the *Orchideæ* are not to be classified in anything like natural sequence based upon root-structure alone, and we have thought, therefore, that it would be the most convenient to treat the different types of roots by themselves, and regardless of the natural affinities of the genera or species in question. In this way a general idea of the root-structure may be obtained with less difficulty.

The following types may be distinguished as characteristic of the terrestrial species:

A. Roots slender with the leptome and hadrome located in one central-cylinder.

B. Roots tuberous with the leptome and hadrome located in one central-cylinder.

C. Roots tuberous with several cylinders of leptome and hadrome.

Of these types the first, A, represents several cases of deviation from the ordinary root-structure by the presence of a velamen for instance (*Tipularia*, *Bletia*), by a peculiar striate thickening of cortex (*Liparis*), and by the development of a true pith (*Calypso*, *Goodyera*, *Habenaria*, etc.). The second type, B, is especially characteristic by reason of its large dimensions, due to numerous layers of cells in cortex and pith, while the third, C, as already indicated, possesses several mestome-cylinders.

Type A.

Cypripedium acaule Ait., *C. pubescens* Willd., *C. guttatum* Swtz., *C. montanum* Dougl., *C. fasciculatum* Kellogg, *C. Californicum* Gray and *C. arietinum* R. Br.

In the genus *Cypripedium* the root-structure comes nearest that of a normal root and may be described as follows: The epidermis is thin-walled in all the species enumerated above, with the exception of *C. guttatum*, in which the outer cell-wall is slightly thickened; root-hairs are usually abundant. A thin-walled hypoderm of one layer is, also, noticeable, but is

moderately thickened in *C. guttatum.* The cortical parenchyma consists of from 6 to 8 strata with large deposits of starch; it is quite compact, but thin-walled, except in *C. pubescens*, where the cell-walls are thickened and porose. Endodermis is mostly thickened as an U-endodermis outside the leptome, but it is otherwise thin-walled, and the following deviations may be mentioned. In *C. acaule*, *guttatum* and *arietinum* 3 to 4 thick-walled cells were observed outside the leptome, while 6 in *C. Californicum;* in *C. pubescens* and *C. montanum* 2 to 4 cells were thickened like an O-endodermis outside the leptome, while in *C. fasciculatum* the entire endodermis was found to be thin-walled throughout. The pericambium is only represented by a single continuous layer in all the species; it is thin-walled except in *C. arietinum.* The rays of the hadrome are very broad and meet in the center; they average from 5 to 10, 8 to 10 being the characteristic of *C. montanum;* a thick-walled pith forms a small central group in *C. Californicum*, but not in the others. The leptome is well developed in large groups alternating with the rays of the hadrome.

None of the roots were found to be contractile, and hyphæ were noticed in: *C. pubescens* (epidermis, hypoderm and cortex), *C. fasciculatum* (cortex) and *C. guttatum* (endodermis and pericambium).

Epipactis gigantea Dougl.

Epidermis, hypoderm and cortex are all thin-walled, and much starch is deposited in the cortical parenchyma. The endodermis is thin-walled throughout with the Casparyan spots plainly visible and with contents of starch; the pericambium forms a closed ring around the leptome and hadrome; it consists of only one layer, the cells of which are prominently thickened outside the leptome, but otherwise thin-walled. Five broad rays of hadrome extend to the center of the cylinder and alternate with large, roundish groups of leptome. No hyphæ were observed.

Listera cordata R. Br. and *L. australis* Lindl.

The structure of the roots of these two species is almost identical, and the difference depends merely upon the relative development of hairs, which are very numerous and long in the former species, but quite scarce in the latter; moreover, the leptome constitutes groups of quite large dimensions in *L. cordata*, but not in the other species; otherwise the structure is identical. Epidermis and hypoderm are thin-walled, and the cortex which occupies the greater portion of the root is composed of about 5 layers, the cells of which are very large, thin-walled and filled with starch; the intercellular spaces are

narrow. Endodermis is moderately thickened all around, while the pericambium is thin-walled and continuous in *L. cordata.* Five narrow rays of hadrome meet in the center with five relatively wide vessels, and alternate with roundish groups of leptome; the conjunctive tissue is thin-walled and is only to be observed between the vessels, but not in the center of the cylinder. Hyphæ were observed in epidermis, hypoderm and cortex of *L. cordata*, but not in *L. australis.*

Pogonia ophioglossoides Nutt., *P. verticillata* Nutt. and *P. divaricata* R. Br.*

Epidermis is thin-walled and densely covered with hairs in *P. ophioglossoides* and *divaricata*, but less so in the third species. The hypoderm is thin-walled in *P. ophioglossoides*, slightly thickened in the others. The cortex is composed of 6 to 9 layers of thin-walled cells; it is quite open in *P. ophioglossoides*, but very compact in the other species. Starch was only found in *P. divaricata.* Endodermis is thin-walled throughout in *P. ophioglossoides* and *P. divaricata*, but in *P. verticillata* there is one thick-walled cell outside each group of leptome. The thin-walled pericambium is continuous in *P. ophioglossoides*, but is irregularly interrupted by the protohadrome vessels in the two other species. The leptome represents quite large and roundish groups alternating with narrow rays of hadrome; 5 rays were observed in *P. ophioglossoides*, 6 in *P. divaricata* and 8 in the third species; the hadrome extends to the center of the cylinder in *P. ophioglossoides*, but not in the other species. Hyphæ were found in the hypoderm and cortex of all three species.

Calopogon pulchellus R. Br., *C. multiflorus* Lindl. and *C. parviflorus* Lindl.

The root-structure is very uniform in these species and resembles that of *Pogonia*, especially *P. ophioglossoides.* Epidermis and hypoderm are thin-walled in all three species, and the cortex, which, also, is thin-walled, consists of about 8 layers with narrow intercellular spaces; no starch was observed in the cortex. The endodermis is thin-walled throughout, with the spots plainly visible. In the central-cylinder we find a thin-walled pericambium in the two first species, but one moderately thickened in *C. parviflorus*; it is continuous in *C. pulchellus*, but we were unable to trace the exact location of the protohadrome vessels in the other species, whether these had broken through the pericambium or not. Five, and quite broad, hadromatic rays were observed in *C. pulchellus* and *C. parviflorus*, but only three in *C. multiflorus*; the innermost vessels are relatively wide and border on a small, but very distinct, cen-

* Compare this Journal, vol. ix, 1900, p. 13.

tral group of slightly thickened parenchyma. The leptome occurs as small, roundish groups in transverse section. Hyphæ were found in the cortex of *C. multiflorus* and *C. pulchellus*, but none in the third species.

In the following genera of this same type the roots are quite slender, but possess in contradistinction to those described in the preceding, a well developed central parenchyma, which evidently represents a true pith, homologous with the pith of the stem.

Habenaria repens Nutt.

This species is a native of very damp places, and when growing in water the very long roots produce root-shoots. A thin-walled epidermis with few hairs and a hypoderm surround a cortex of about 20 layers of thin-walled cells, of which the outermost 4 constitute a compact and persisting tissue, while the interior 16 are traversed by numerous lacunes from the very wide intercellular spaces; only a little starch, but many bundles of raphides were observed in the cortex, besides hyphæ in the peripheral strata. The cortical parenchyma is, thus, very open, and in several roots, in the entire length of these, a well defined duct was furthermore observed, surrounded by a sheath of very small, thin-walled cells; neither liquid or solid contents were observed in this duct, and its function may evidently be for osmotic exchange of gases.

The endodermis and the continuous pericambium are both thin-walled. In regard to the hadrome and leptome, the former does not occur in rays, but merely as small groups, from 6 to 15, each consisting of a few, 2 to 5, mostly wide vessels, which to a more or less extent alternate with the equally small groups of leptome. The arrangement of the hadrome in proportion to the leptome is somewhat irregular, and we observed several cases where the leptome was really located in front of the hadrome, thus imitating the radial position of these same elements in the stem; in other cases the vessels were on each side surrounded by a group of leptome with the two proto-leptome cells very distinct (fig. 1), as in mestome-bundles of the hadrocentric type, and this position was frequently observed in *H. repens.* The larger portion of the central cylinder consists of a thin-walled pith with deposits of starch.

Arethusa bulbosa L.

The epidermis is thin-walled and densely covered with long hairs; there is, also, an hypoderm, but not easily distinguishable from the cortex. The latter consists of about 6 compact layers with many hyphæ, but without starch. Endodermis and the continuous pericambium are both thin-walled and surround

6 short, but broad groups of rather narrow vessels, alternating with a corresponding number of small groups of leptome, while a pith occupies the greater inner portion of the central-cylinder.

Calypso borealis Salisb.

The structure of the root is almost identical with that of the preceding, and the only differences observed were as follows: the hypoderm is very distinct and the cell-walls are slightly thickened; the cortical parenchyma is a little broader and quite open, the intercellular spaces being relatively wide; the hadrome occurs only as small, 3 to 6, groups of vessels, alternating with the leptome and separated from the center by a large mass of thin-walled pith.

Goodyera pubescens R. Br., *repens* R. Br., *Menziesii* Lindl. and *tesselatum* Lodd.

In respect to the root-structure these species resemble each other very much, and we find in these the same delicate structure of the various tissues, as described above as characteristic of *Arethusa* and *Calypso.* The roots are very hairy, the epidermis, the hypoderm, the cortex, the endodermis and the continuous pericambium are all thin-walled; of these, the cortex consists of about 6 layers in *G. repens* and *tesselatum*, of 8 in *G. pubescens*, and of about 12 in *G. Menziesii;* it is quite compact in all the species except in *G. tesselatum*, in which the intercellular spaces are much wider than in the other species. The hadrome and leptome constitute small groups, when viewed in transverse sections, the former with 4 to 8 vessels in each group, widely separated from the center of the cylinder by a large, starch-bearing and thin-walled pith. The number of hadromatic groups is somewhat variable within the species examined; thus 4 were observed to be characteristic of *G. repens*, 5 of *G. tesselatum* and 6 of the other species. No hyphæ were found in the internal tissues of *G. repens* or *G. tesselatum*, but in the cortex of the others.

Chloræa Austinæ Gray.*

Although the roots of this plant are relatively strong, much more so than in any of the other *Orchideæ* described above, the structure does not reveal any very pronounced mechanical

* The statement by Mr. MacDougal (Bull. Torrey Club 26: 528, 1899) that "this plant is to be added to the list of chlorophylless plants furnished with stomata" is not correct, since we have observed the presence of chlorophyll-grains in the ovary; the guard-cells of the stomata as well as the adjoining epidermis-cells are well supplied with chlorophyll. The description and the figures furnished by this author (l. c.) are altogether very inexact.

equipment. The only tissues which exhibit some thickening are the endodermis and the large, central parenchyma; of these the former is, however, only thick-walled just outside the leptome, and only moderately so. The pith is not thickened very much either, but it occupies such a prominent part, that it necessarily contributes a great deal to the toughness of the root. But the other tissues are thin-walled, and the cortex is composed of 15 compact layers, densely filled with starch and some hyphæ. The pericambium is continuous and surrounds 6 broad rays of hadrome with rather narrow vessels, arranged very regularly in alternation with the large groups of leptome, and border on the very prominent, central pith.

Aplectrum hyemale Nutt.

The densely hairy epidermis, the hypoderm and cortex are all thin-walled, and the last of these consists of about 9 layers with narrow intercellular spaces; no starch or hyphæ were observed, but bundles of raphides. The endodermis and the continuous pericambium are, also, thin-walled and surround 9 broad rays of hadrome, alternating with large, roundish groups of leptome with a central mass of thin-walled pith.

Liparis liliifolia Rich.

The very slender roots show a very feeble structure since all the tissues from epidermis to pith are of a very delicate texture. The epidermis bears many long hairs; the hypoderm is well differentiated from epidermis and cortex by the cells being somewhat stretched radially and almost regularly pentagonal. The cortex consists of about 8 layers and contains a few hyphæ, but no starch; it seems characteristic of certain species of the genus that some of the cells of the cortex exhibit the same spiral thickening of the wall as is well known from the roots of epiphytic genera, a fact that has already been mentioned by Irmisch.* The endodermis is very thin-walled and shows the spots very plainly; the pericambium is continuous and surrounds 12 small groups of hadrome, each with a few vessels, and a corresponding number of small groups of leptome, while a large pith occupies the inner portion of the central-cylinder.

Tipularia discolor Nutt.

As stated above, the roots of this plant show the remarkable structure of possessing a velamen of 3 to 4 layers inside a thin-walled, very hairy epidermis. However this velamen differs from that of the epiphytic *Orchideæ* by lacking the character-

* Beiträge zur Biologie und Morphologie der Orchideen, Leipzig, 1853, p. 34.

istic spiral or simply striate thickening of the cell-walls; otherwise the structure is identical. There, is, furthermore, an exodermis of exactly the same structure as we know from the epiphytic genera. The cortical parenchyma is thin-walled and consists of about 8 layers of roundish cells with narrow intercellular spaces; many hyphæ, but no starch, was observed in this tissue. The endodermis and the continuous pericambium are both thin-walled and surround 5 short rays of hadrome, alternating with 5 small groups of leptome; a pith occupies the inner portion of the central-cylinder.

Bletia verecunda Sw.

In several respects the root-structure of *Bletia* agrees with that of *Tipularia*, but some, and indeed quite important, deviations were noticed. These consist in the more typical development of velamen, the cell-walls of which exhibit the characteristic fine and spiral thickening peculiar to this tissue; moreover by the presence of a double pericambium, which is moderately thickened and to the same extent as the hadrome, thus the position of the proto-hadrome vessels in proportion to the pericambium could not be made out satisfactorily. The hadrome forms 8 short and broad rays alternating with large, roundish groups of leptome, inside of which there is a large, thin-walled pith with intercellular spaces of quite considerable width.

These roots, described above, belong to the first type, all being relatively slender and possessing only one, central-cylinder. In several respects they agree with the second type, in which, however, the dimensions of the roots have increased to such an extent as to deserve the term "tuberous" on account of the much broader zones of the cortex and pith, besides by the larger number of rays or better "groups" of hadrome and leptome.

Type B.

Spiranthes gracilis Big., *S. simplex* Gray, *S. præcox* Wats., *S. Romanzoffiana* Cham., *S. cernua* Rich., *S. cinnabarina* Hemsl. and *S. Asagræi* Schaff.

Even when the roots are quite numerous, as in the last two species, they, nevertheless, retain the same swollen aspect as when they are but few in number or single, as in *S. simplex*. The internal structure is, also, very uniform in these species, and not very different from those described above, but pertaining to other genera.

Common to these species of *Spiranthes* is a thin-walled epidermis with many hairs, besides a hypoderm of one layer, the cells of which are smaller than those of the adjoining cortex.

And as already described by Irmisch (l. c.) as characteristic of the European *S. autumnalis* Rich., the cells of epidermis show the same spiral thickening as we find in the velamen of the epiphytic genera, besides that a similar thickening of the cell-wall is, also, to be observed in the hypoderm of *S. cinnabarina* and *Asagræi.* The cortex is thin-walled and the cells of the innermost layers are very often stretched radially; the number of layers varies somewhat, but is usually about 15, and the contents consist mainly of starch, except in the last two species, where only hyphæ were observed; it seems altogether as if the function of these fleshy roots of *Spiranthes* is to store starch and not water, although the nature of the habitat might suggest that water-reservoirs would be needed. In *S. simplex* and *S. præcox* no hyphæ were observed in any of the tissues, but in the other species the roots proved to be real *mycorhizæ.* As to the innermost layer of the cortex, the endodermis, this seems to be invariably thin-walled in the species examined and shows the Casparyan spots very plainly. The pericambium is represented by only one layer; it is very irregularly interrupted by the proto-hadrome vessels in *S. gracilis*, *S. simplex* and *S. Romanzoffiana*, but in certain roots of the last species it occurred, also, as a continuous ring, the proto-hadrome being located inside. In *S. præcox* the pericambium was found to be continuous near the base of the root, but interrupted near the apex of same. The rays of the hadrome, from 12 to about 20, are very short in all the species and contain but a few vessels, alternating with similarly very small groups of leptome, while the greater portion of the central-cylinder is occupied by a large mass of thin-walled parenchyma, a true pith.

Type C.

The roots of this type are more or less tuberous and contain several cylinders of leptome and hadrome.

Orchis spectabilis L.

If we examine the tuberous root below the hibernating bud, we notice the following structure. Epidermis is thin-walled and there are many root-hairs. Underneath the epidermis is a thin-walled cortex of about 8 layers containing starch and hyphæ, and which borders on 2 mestome-cylinders separated from each other by a few layers of parenchyma, which shows the same structure and contents (starch) as the peripheral cortex. Each mestome-cylinder is surrounded by a thin-walled endodermis, inside of which is a pericambium, which is broken by the proto-hadrome vessels in several places. The hadrome constitutes about 12 irregular and very short rays, which alter-

nate with a corresponding number of leptomatic groups, while a broad pith occupies the inner portion of the cylinder.

The same structure is to be observed in the slender roots of the same rhizome, with the only exception that these contain only one, central mestome-cylinder, the elements of which correspond well with those of the tuberous root, there being about 15 short, hadromatic rays and small groups of leptome surrounding a large, central pith.

Platanthera.

In North America the genus is exceedingly well represented, and occurs with several very distinct types, distinct not only in respect to their flowers, but also in regard to their vegetative organs. The slender, creeping rhizome of *P. rotundifolia* Lindl. is provided with several slender roots, the structure of which is so near that of *P. obtusata* Lindl., that they may be treated together. But in all the other species of the genus examined, the roots, especially the one beneath the hibernating bud, are more or less tuberous, and exhibit a structure that is nearly identical with that of the other secondary, but more slender, roots of the same rhizome.

P. rotundifolia Lindl. and *P. obtusata* Lindl.

Characteristic of the roots of these species is the sparingly hairy epidermis and the lack of any well defined hypoderm. The cortex is thin-walled in both, quite compact in *P. obtusata*, but rather open and not so broad in the other. Large deposits of starch besides hyphæ were noticed in *P. obtusata*, but only hyphæ in *P. rotundifolia*. Two mestome-cylinders of equal diameter are imbedded in the cortex near the center of the root in *P. obtusata*, while there are two large and one much smaller in the other. These mestome-cylinders are, thus, separated from each other by some strata of parenchyma, which may be properly defined as pertaining to the cortex, with which it agrees in regard to structure. Each of these mestome-cylinders has a thin-walled endodermis and pericambium, the latter being continuous in *P. obtusata*. The rays of hadrome (3 in *P. obtusata*, 1 to 5 in *P. rotundifolia*) are very short and consist of but a few vessels, which, together with small groups of leptome, border inward on a thin-walled pith, which is very prominent in *P. rotundifolia*, but rather inconspicuous in the other species.

P. orbiculata (Torr.) and *P. Hookerii* (Torr.).

Habitually these species are very much alike and very distinct from the other North American species of the genus; their root-structure is somewhat different. This difference,

however, depends merely upon the number and relative size of the mestome-cylinders, there being 4, 2 large and 2 small, in *P. orbiculata*, but 8, and all very small, in the other. Besides this variation as to size, their arrangement is, also, quite distinct, since they are located in one ring in *P. orbiculata*, but in two in the other species. Otherwise the structure is identical; the epidermis, hypoderm, cortex, endodermis and pericambium are all thin-walled, and deposits of starch besides raphides were observed in the cortex of *P. orbiculata*, hyphæ, on the other hand, in *P. Hookerii*. Moreover there are noticed 15 short rays of hadrome in the large cylinders of *P. orbiculata*, but only 5 in those of *P. Hookerii*. A central pith was observed in each of these mestome-cylinders and of both species.

The more slender roots show the same structure as the tuberous, described above, but they contain a correspondingly small number of mestome-cylinders, viz: 3 to 4 in *P. Hookerii*, and only 2 in *P. orbiculata*.

In the remaining species of *Platanthera*, which we have examined: *P. dilatata* (Gray), *hyperborea* (Lindl.), *ciliaris* (R. Br.), *psychodes* (Gray), *cristata* (R. Br.) and *tridentata* (Hook.), the roots show an almost identical structure, since the principal difference observable mainly consists in their relative size, their length, thickness and corresponding number of mestome-cylinders, characters of no great importance when we bear in mind the fact, that the tuberous development of such roots is extremely variable and often depending upon certain conditions of the substrate or upon the individual strength of the specimen.

In beginning with the tuberous roots, the epidermis is quite hairy in some species, but merely papillose in others, for instance *P. ciliaris* and *P. psychodes;* this covering with hairs is especially well marked in specimens from *Sphagnum*-bogs. A hypoderm of a single layer is generally present, but seems to lack *P. dilatata*. The cortex is always thin-walled and contains starch, but the number of layers is very variable even in specimens of the same species; hyphæ were observed in all the species except *P. ciliaris*.

The innermost portion of the root is occupied by a large parenchymatic tissue, which, also, contains starch and which is hardly to be distinguished from the cortex; sphærocrystals were observed in great abundance in *P. ciliaris* and *cristata*. The mestome-cylinders occur, sometimes, in several more or less concentric rings, but are mostly somewhat irregularly scattered, especially when their number is very large, as in the thickest roots of *P. ciliaris*. Their number and relative development is variable, but they contain usually from 1 to 5

rays of hadrome with a corresponding number of leptome-groups (fig. 4). The endodermis and pericambium (End. and P. in fig. 4) are constantly thin-walled, and the latter was found to be continuous in some, but interrupted in others of these small mestome-cylinders within the same tuberous root. A very small, central pith was observed in *P. ciliaris* and *cristata*, but not in the others.

If we compare this structure of the tuberous with the slender roots of these same species, there seems to be no other difference than there being a much smaller number of mestome-cylinders in the latter.

Of the three types of roots observable in our terrestrial *Orchideæ*, the third category emphasizes those in which several mestome-cylinders are present instead of but one, and this peculiarity may be briefly described in connection with the anatomical data, mentioned above. The fact that these tuberous roots contain several, isolated cylinders provided with a special endodermis and pericambium, has given rise to various views regarding their morphological identity: whether the "tubers," as they are frequently called, might represent 1) the basal, swollen part of the bud-axis, 2) a single root, 3) a concrescence of several roots or 4) a concrescence of a stem-portion with leaves and roots. Of these the most generally accepted theory is the one which explains the origin of the tuber as being a concrescence of several roots, very ably discussed by Van Tieghem and others.

But the definition tending to explain the tuber as being the result of a concrescence of a stem-portion with leaves and roots, as proposed by Germain de St. Pierre,* has not been approved by others. Nevertheless, as will be shown in the following pages, this definition does not only seem to be well founded, but is, indeed, the only conceivable one, as far as concerns the tuberous body beneath the hibernating bud in North American *Ophrydeæ;* we may illustrate this by the rhizome of *Platanthera dilatata* (fig. 2). The rhizome of this species is relatively slender and the hibernating bud is prominently removed from the mother shoot by the descending stolon (*St.* in fig. 2); the bud itself (*b*) appears as if it were lateral, since the stolon gradually passes over into the long, tuberous body (*r*) underneath the bud, the so-called "tuber" of most authors. The bud, however, is terminal and its apparently lateral position is due to the growth of the stolon, the direction of which is neither horizontal nor vertical, but simply descending. As may be seen from the figure the basal region of the bud with its rudimentary leaves and young roots is located on the upper, the dorsal, face of the stolon,

* Bull. Soc. Bot. de France, vol. 2, p. 659, 1855.

between the lines 4 and 10. Underneath or better "behind" the bud, as the figure shows, is a cylindrical body between the lines 4 and 10, which cannot possibly be defined as representing a stem (stolon) or a root alone, but appears to be a concrescence of both; the result of our anatomical investigation is in favor of this explanation.

In our figure 2, the dotted lines indicate the places where the most important sections have been laid, and the general structure of the rhizome may be briefly described as follows: At its very base (*st.*) the stolon exhibits a structure like that of a typical rhizome with a distinct central-cylinder, surrounded by an endodermis, and with all the minor characters of a stem-portion. But if we examine a section of this same stolon taken a little further down, by the line 2 for instance, the structure is somewhat different, since we observe there two additional, but very small, mestome-cylinders, which are located underneath the central-cylinder; each of these two mestome-cylinders possess an endodermis and a pericambium (End. and P. in fig. 3) and they represent two roots or at least two primordia of such. By continuing our examination of the same rhizome, we observe in section 3 not less than five small mestome-cylinders besides the central, of exactly the same structure as the two described above, and these are very regularly arranged in an arch which is parallel with the lower face of the stolon. At the same time the epidermal structure has become changed, thus the cells on the lower face of the stolon are more or less extended into papillæ and have attained a darker color in contrast to the epidermis of the upper face, which has retained the typical structure of a stem-epidermis. In other words, the stolon has started to become dorsiventral with the development of roots on its ventral face, accompanied by the characteristic epidermal structure.

In following the structure further down to section 4, the large cylinder, formerly central, has become moved nearer the dorsal face of the stolon, and the number of small mestome-cylinders has increased to ten, arranged in two arches parallel with and located near the ventral face. The distinction in regard to the epidermal structure is still more pronounced in this section, and the dorsal epidermis occupies a zone that is much narrower than the ventral. A gradual increase in the number of mestome-cylinders takes place further down, and thirteen were noticed in the sections taken by the lines 5 and 6; furthermore, by 6, the large mestome-cylinder of the stolon is not only still nearer the dorsal face than we observed before, but its pith has become reduced quite considerably in width. And in regard to the bud, the outermost leaf shows here (at 6) a distinct swelling, caused by a cavity at its base. The broad-

est part of the stolon (by 7) contains the bud, and shows, besides, the thirteen small mestome-cylinders, already observed in the section 5, arranged in two arches parallel with the ventral face of the stolon, and with the points of the arches meeting near the central-cylinder of the bud-axis. The large mestome-cylinder is still visible at the line 8 and a little below, but disappears at 9; from here the small cylinders have increased to seventeen, most of which are arranged near the periphery with a few scattered nearer the center. These peripheral mestome-cylinders are quite small and show the same structure as described above; the interior are somewhat larger, but show, nevertheless, an identical structure.

If we now dissect the part of the rhizome located by the line 11, we perceive the structure that has been described so often as characteristic of the "tubers" of *Ophrydeæ:* a large number (23 in this case) of mestome-cylinders, each with a special endodermis and pericambium, and arranged, but not very regularly, in two zones; the distinction between the two epidermal layers (the dorsal and the ventral) has vanished, and the brownish, conical and tuberous body is now covered all around by papillæ and very short root-hairs.

It would thus appear as if at least the upper portion of the tuberous body of the rhizome of *Platanthera dilatata* and the other North American *Ophrydeæ*, which we have examined, is composed of elements pertaining to a stolon, a bud and some roots, instead of being simply a root, a concrescence of several roots or finally a swollen bud-axis. But in offering our support to this explanation, pronounced so many years ago by the French botanist, we are well aware of the difficulty which confronts any investigator who deals with organs that remain in their primordial stage and which are not known to occur otherwise, as the supposed secondary roots of *Ophrydeæ.*

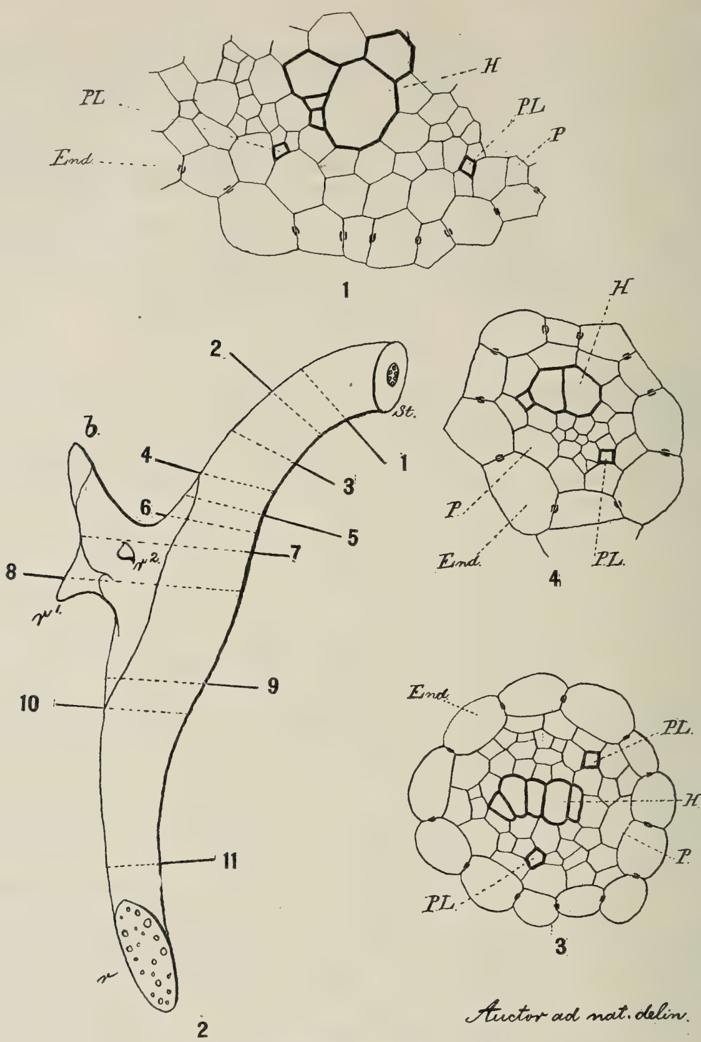
If we had only succeeded in detecting some distinctions in the cortical parenchyma of the stolon, when the supposed roots make their first appearance, so as to be enabled to discriminate between the cortex of the stolon and that of the roots, then there would have been more substantial proof in explaining this organ as a concrescence of roots and stem. But the only distinction which we have noticed depends upon the variation expressed in the epidermal structure, the constant dorsiventrality of the stolon from the first appearance of the secondary roots, and the structure of the small mestome-cylinders being identical with more slender roots of the same species. Of course the word "concrescence" is somewhat misapplied in this particular instance, since these secondary roots have never been observed to be free, not even at the youngest stage of the stolon or of the bud. But otherwise our definition of the

"tuberous body" may from a morphological viewpoint be justifiable, when we compare the rhizome, and especially the arrangement of the roots, with that of other terrestrial *Orchideæ* in which all the roots are free, slender and with only one central-cylinder. In *Arethusa*, for instance, the disposition of the roots is such that if they were united or grown together, they would exhibit exactly the same structure as we have shown being the characteristic of the lower portion of the "tuber" in the *Ophrydeæ*. But the habit of these plants is too distinct to allow us even to imagine ourselves, that such union of the roots in *Arethusa* might be possible.

Summary.

1. A velamen and exodermis is developed in the terrestrial *Tipularia discolor* and *Bletia verecunda*.
2. Some cells of the cortical parenchyma in *Liparis liliifolia* show the same spiral thickening as is known from the epiphytic genera.
3. A similar spiral thickening was observed in the epidermis and hypoderm of several species of *Spiranthes*.
4. The pericambium is composed of two layers in *Bletia verecunda*.
5. The pericambium was observed to be continuous in a number of species pertaining to different genera.
6. The pericambium was observed to be continuous or interrupted in the same root of *Orchis*, *Pogonia verticillata*, various species of *Spiranthes*, etc.
7. Sphærocrystals abound in the inner parenchyma of several species of *Platanthera*.
8. All the roots of *Epidendreæ*, *Neottieæ* and *Cypripedieæ* examined possess only one central-cylinder.
9. A true pith and, sometimes, of quite considerable width was observed in *Tipularia*, *Arethusa*, *Calypso*, *Spiranthes*, *Chloræa*, *Goodyera*, *Habenaria*, *Aplectrum*, *Bletia*, *Liparis*, *Calopogon* and *Cypripedium Californicum*.
10. The cortical parenchyma is traversed by wide lacunes and by a special duct in *Habenaria repens*.
11. The upper portion of the so-called "tuber" of the *Ophrydeæ* examined consists of elements pertaining to a stolon, a bud and some roots; the lower part, on the contrary, of roots alone.
12. The roots of our terrestrial *Orchideæ* very often represent *mycorhizæ*, but not all the roots of the same species, nor of the same specimen.

Brookland, D. C., May, 1904.



EXPLANATION OF FIGURES.

FIGURE 1.—Transverse section of the root of *Habenaria repens*, showing a part of the central-cylinder; *End.* = endodermis; *P.* = pericambium; *P. L.* = proto-leptome; *H* = hadrome. × 320.

FIGURE 2.—Part of stolon with bud and roots of *Platanthera dilatata*, magnified. *b* = apex of the bud; r^1 and r^2 = young roots; *r* = the tuberous root; *st.* = base of stolon. The dotted lines indicate the places where the sections have been laid.

FIGURE 3.—Transverse section of one of the two small mestome-cylinders of the stolon; letters as above. × 320.

FIGURE 4.—Transverse section of a mestome-cylinder from the tuberous root; letters as above. × 320. (Figs. 3 and 4 are both of *Platanthera dilatata;* fig. 3 of a specimen from Vermont, fig. 4 of a specimen from Mt. Elbert in Colorado.)

ART. XXVI.—*A Study of the Structure of Paleozoic Cockroaches, with Descriptions of New Forms from the Coal Measures;* by E. H. SELLARDS.

[Continued from p. 134.]

Etoblattina coriacea sp. nov. Text-figure 29; and Plate I, Figure 11.

Tegmina long, very slender, pointed at the apex, costal border slightly arched, inner border full, very thick; nervation obscure. Subcosta extending to the apex. Cubitus comparatively short, reaching only a little beyond the middle of the wing. Anal area of medium extent; anal veins about ten in number, simple or forked.

The wing is of especial interest, because of its coriaceous texture in which the veins are almost obscured. Only a few terminal branches of the radius and media can be made out. The branches of the subcosta are entirely obscured. A noticeable feature of the wing is the sharp angle made by the anal area.

Formation and Locality.—Upper Coal Measures, Lawrence, Kansas. Type in the University of Kansas collection.

Etoblattina Hilliana ? Plate I, Figure 4.

Scudder, Bull. U. S. Geol. Surv., No. 124, 1895, p. 99, pl. viii, fig. 11.

The wing of Figure 4, Plate I, is doubtfully referred to *E. Hilliana.* The subcostal area is broader than in the type, and the media apparently is not so sinuous.

Formation and Locality.—Coal Measures, Mazon Creek, Illinois.

Spiloblattina.

Scudder, Proc. Acad. Nat. Sci. of Philadelphia, p. 35, 1885; Mem. Boston Soc. Nat. Hist., vol. iv, p. 461, 1890.

The genus *Spiloblattina* was proposed by Scudder to include four species of cockroaches from Fairplay, Colorado. The essential characters of the genus are the wide divergence of the radius and media, and especially of the media and cubitus beyond the middle of the wing, and their subsequent convergence enclosing an elongate or ovate area, the "stigma." Associated with these are other well-defined characters, as the thin tegmina marked with light and dark patches, and dark bands accompanying the veins. The relative distribution of the veins and their areas in this genus are practically the same as in some species of *Etoblattina.* Nevertheless, the *Spiloblattina* group of species, with thin variegated front and hind wings, is evidently a natural one, and without doubt merits generic rank. The sterna of *Spiloblattina* appear from some Kansas

specimens to have a shape different from those of *Etoblattina*, being pointed instead of rounded posteriorly. *Spiloblattina* has not been previously recognized in the Coal Measures, the type having come from deposits which are either Triassic or Permian, but an examination of some Coal-Measure forms from new material convinces the writer that the genus is represented in these formations. In describing the cockroaches from Richmond, Ohio, Professor Scudder noted that some of the species approached closely to *Spiloblattina*, remarking that the disposition of the media and cubitus of *Etoblattina ramosa* is "much after the fashion of *Spiloblattina*." A reëxamination of *Etoblattina maledicta*, a closely related species, leads to its reference in the present paper to *Spiloblattina*.

Spiloblattina maledicta. Plate I, Figures 5, 6, and 10; Text-figures 26 and 27.

Etoblattina maledicta Scudder, Bull. U. S. Geol. Surv., No. 124, p. 83, pl. 6, figs. 1–3, 1895.
Etoblattina benedicta Scudder, ibid., p. 84, pl. 5, figs. 14–15.

Tegmina narrow, two and one-half times as long as broad, costal border slightly arched, inner border nearly straight; tegmina broadest at the extremity of the anal area, apex obtuse. Subcostal area narrow, extending a little beyond the middle of the tegmina; branches mostly simple and oblique. The radius reaches nearly to the apex. The first branch is given off at about the extremity of the basal third, sometimes as early as the end of the basal fourth, and is usually twice forked. Three or four other simple or deeply forked branches pass to the border. The media gives off its first branch somewhat beyond the middle. The main vein and its branches fill the apex. The cubitus varies in extent, either reaching well on to the apical margin, its greatest extent being obtained by an outward curve near the termination, or, lacking the curve, ending short of the apical margin. The first five or six branches are straight, mostly simple, and parallel; the others are more oblique, not uniform in number, curved, and sometimes forked. The anal area extends approximately to the end of the basal fourth, is clearly marked off, and has six or seven mostly simple veins. The main veins of the wing originate close together somewhat above the middle of the base. The veins diverge in the central part, enclosing elongate, light-colored areas. The tegmina are delicate and thin, the veins thin, although appearing heavy in places because of the dark-colored bands accompanying them. The alternate light and dark areas give the wing a striking appearance (Figures 5, 6, Plate I). A dark band extends along the costal border obscuring the tips of the

veins. Similar bands accompany the radius, media, and cubitus. Light areas occur in the interspaces between the main veins as well as between some of the branches. Two conspicuous, large, light spots, with irregular boundaries, occur in the apical part of the wing. The agreement with the types of the species from Richmond, Ohio, is very close. The two light spots on the apical part of the wing are not described for the type, probably because the apex was not well preserved.

In the original description of *E. benedicta*, Scudder expressed doubt as to its specific separation from *E. maledicta*. The differences which seemed to distinguish the two forms were the more arched costal border of *E. benedicta*, the less extent of the cubital area, and the approximation in the point of origin of the two radial branches. More than forty tegmina of this species are at hand for comparison. Camera lucida sketches of numerous wings show that, while those with a short cubitus have, as a rule, a more arched border, there is an almost con-

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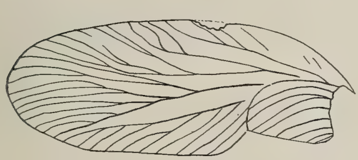

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FIGURES 26, 27.—*Spiloblattina maledicta* Scudder, sp.; illustrating the extremes of variation of the species; ×2. Figure 27, typical wing with extended cubitus; Figure 26, form with arched costal border and short cubitus. Originals in University of Kansas Museum.

tinuous series between, with no break sufficient to serve as a specific character. Figures 26 and 27 show the extreme limits in the extent of the cubitus, the two figures corresponding closely to the type figures of the two forms. In one the cubitus falls decidedly short of the apical margin, while in the other it extends by an outward curve and more numerous branches well on to this border. Other specimens show that the cubitus is variable in extent, and individuals can be found presenting a condition so nearly intermediate that a specific separation can hardly be sustained on this character. The third distinction given, the approximation in the point of origin of the first and second radial branches, is not constant. Occasionally a wing is seen having both a long cubitus and a close approximation in the point of origin of the first and second radial branches.

Hind Wings.—The hind wings are thin, and ovate in shape. The costa is submarginal, straight, and simple. The subcostal

area is narrow, has a few superior oblique short branches, and extends to, or beyond the middle. The radius reaches nearly to the apex and gives off about three oblique, widely forked, or simple branches. The media has four or five superior branches which fill the apex. The cubital area is well developed, the branches oblique, straight, parallel, and mostly simple. The anal area is supported by a few simple radiating veins. Eleven hind wings of this species have been obtained, one in direct connection with the tegmina. The hind wing is of even thinner texture than the front, and is also marked by light and dark areas. A dark area extends along the costal border and dark bands accompany some of the veins.

A few specimens preserving parts of the body, especially the abdomen, show evidence of light and dark areas on the body and are, for this reason, provisionally referred to this species (Figure 22). The abdomen is rather slender; the edges of the terga are of moderate extent. The sterna differ from those of *Etoblattina*, being pointed at the posterior angles. Length of the tegmina, 22 to 25^{mm}; width, 8 to 9^{mm}. Hind wings, 16 to 18^{mm} long; 8 or 9^{mm} wide.

Formation and Locality.—Lawrence Shales, Upper Coal Measures, Lawrence, Kansas.

Gerablattina.

Scudder, Mem. Bost. Soc. Nat. Hist., vol. iii., p. 97, 1879.

Gerablattina arcuata sp. nov. Text-figure 1; and Figure 7, Plate I.

Tegmina about twice as long as broad, outer border strongly arched, the apex rounded; inner border nearly straight, interrupted by the anal area. Subcosta arched parallel to the inner border, reaching three-fourths the length of the wing, branches numerous, simple, curved, thin, and parallel. The radius is but slightly developed, branches first beyond the middle of the wing, and falls a little short of the apex. The media, like the radius, occupies a comparatively small area, and remains simple until beyond the middle of the wing, its four simple, oblique branches filling the apex. The cubitus is strongly developed and reaches almost to the apex. The first five branches are simple and nearly straight, the others are more oblique, closer, and curved. The anal area is well marked and has about seven simple veins. In texture and general appearance this species presents considerable similarity to *S. maledicta*. The tegmina, however, are much more strongly arched, and the subcosta has a greater development correlated with a reduction in the radius. Length of the tegmina, 24^{mm}; width, 9^{mm}.

Formation and Locality.—Lawrence Shales, Upper Coal Measures, Lawrence, Kansas. Type in Kansas Museum.

Schizoblattina gen. nov.

Small cockroaches; veins of the tegmina numerous, much branched, and united in all parts of the wing by frequent, comparatively strong, cross veins. The main vein trunks are free almost or quite to the base, and show a tendency to disappear by dichotomy. Subcostal area broad at the base, strongly developed, with numerous superior branches. Some of the anal veins end on the anal furrow.

Schizoblattina is apparently not closely related to any described genus. *Neorthoblattina albolineata* Scudder, a small species occurring near Fairplay, Colorado, resembles it in its numerous, much branched veins united by straight, comparatively strong, cross veins. The anal veins also present

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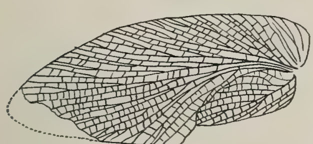

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FIGURE 28.—*Schizoblattina multinervia* sp. nov.; × 2.
FIGURE 29.—*Etoblattina coriacea* sp. nov.; × 2. Anal area restored from the obverse side of same specimen. Original in University of Kansas Museum.

the peculiarities of *Schizoblattina*, the first anal giving off several branches which run toward the anal furrow. The other species, including the type of *Neorthoblattina*, have two of the main veins more or less completely amalgamated. That this is also true of *N. albolineata* is not clear from the figure, nor is this point specifically mentioned in the description. It is evident from the peculiar disposition of the anal veins, the occasional cross nervules, and the prolific branching of the veins, that *N. albolineata* is markedly different from the other species of the genus in which it is at present placed, and as far as it is possible to judge from the illustration seems to fall more naturally in *Schizoblattina*.

The geological age of the Fairplay beds, from which *N. albolineata* came, is unsettled, the formation having been referred both to the Triassic and to the Permian.

Schizoblattina multinervia sp. nov. Text-figure 28.

This Journal, vol. xv, pl. vii, fig. 6, April, 1903.

Tegmina small, a little more than twice as long as broad. Costal and inner borders both arched, sloping gradually and equally to the apex, which is placed about the middle of the

wing. Tegmina strong, supported by numerous close branches with frequent, comparatively strong, cross veins in all parts of the wing. Subcostal area broad at the base, triangular, extending a little beyond the middle of the wing. The branches are numerous, once or twice forked, the first arising from near the base and the distal more oblique than the proximal. The radius is clearly distinct from the subcosta. The first branch is given off about the end of the basal fourth of the wing and is two or three times branched. The main vein runs in a sinuous course, reaching the costal border a little short of the apex, giving off three or four oblique, once or twice forked branches. The media is close to, but distinct from, the radius. It dichotomizes first beyond the first branch of the radius, near the end of the basal fourth of the wing. Both branches dichotomize frequently, the numerous divisions filling the distal third of the inner margin and the apex. The cubitus divides early. The branches, dichotomizing two or three times, fill the middle third of the inner margin. The anal area is of moderate extent. The first anal vein gives off five superior branches. The first and second of these, arising close to the base, are once forked, the other three being simple. The first four run toward the anal furrow, the fifth turns down parallel with the furrow and passes to the inner border. A forked inferior branch is also given off from the first anal. The greater part of the area is thus occupied by the first anal and its branches. Three other short curved veins can be seen close to the inner border. Length of tegmina, 17^{mm}; breadth, 7^{mm}.

Formation and Locality.—Lawrence Shales, Upper Coal Measures, Lawrence, Kansas. Type in the writer's collection.

Archoblattina.

Megablattina, Sellards (non Brongniart), this Journal, vol. xv, p. 312, April, 1903.
*Archoblattina**, Sellards, ibid., vol. xv, p. 488, June, 1903.

Large cockroaches; body bulky, abdomen broad and fleshy; pronotum large, longer than broad, approaching a rectangular form, truncated or slightly emarginate in front, emarginate at the sides, broadest and rounded behind; front and hind wings large, overlapping the abdomen.

Archoblattina Beecheri. Text-figures 30, 31, and 32.

Megablattina Beecheri Sellards, this Journal, vol. xv, p. 312, April, 1903, pl. viii.
Mylacridæ sp.? Scudder, Bull. U. S. Geol. Surv., No. 124, p. 55, 1895, pl. ii, fig. 4.
Blattina sp.? ibid., p. 142, pl. x, fig. 16.

Tegmina large, about three times as long as broad, costal border arched only very slightly, inner border nearly straight.

* *αρχων*, prince.

Subcosta curved parallel with the costal border and extending two-thirds the length of the wing, giving off numerous simple or compound branches. Radius forked about one centimeter from the base, and consisting of a few long, nearly parallel branches, which strike the border near, but above, the apex. The media forks first near the middle of the wing; the median

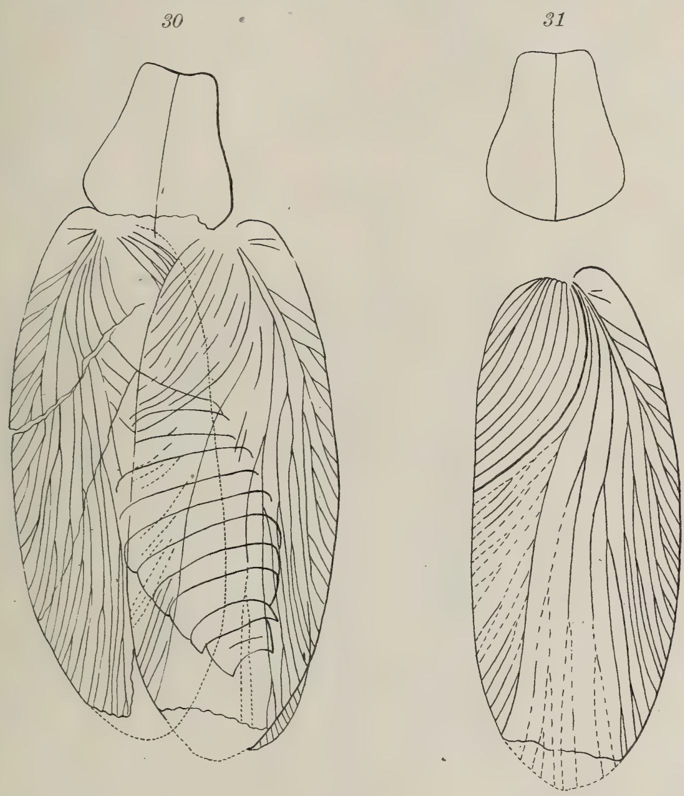

FIGURE 30.—*Archoblattina Beecheri* Sellards; type specimen; dorsal view.
FIGURE 31.—The same; pronotum and wing partly reconstructed.
Original in Yale University Museum.
Both figures are natural size.

area is narrow, consisting of a few long veins running to about the apex. The cubitus, although imperfectly preserved in the specimen at hand, is evidently of great extent, apparently reaching to, or beyond, the inner angle of the wing, and giving off numerous inferior branches. The anal area is of medium extent, strongly marked off by a prominent furrow, and consists of nine or ten simple or forked veins.

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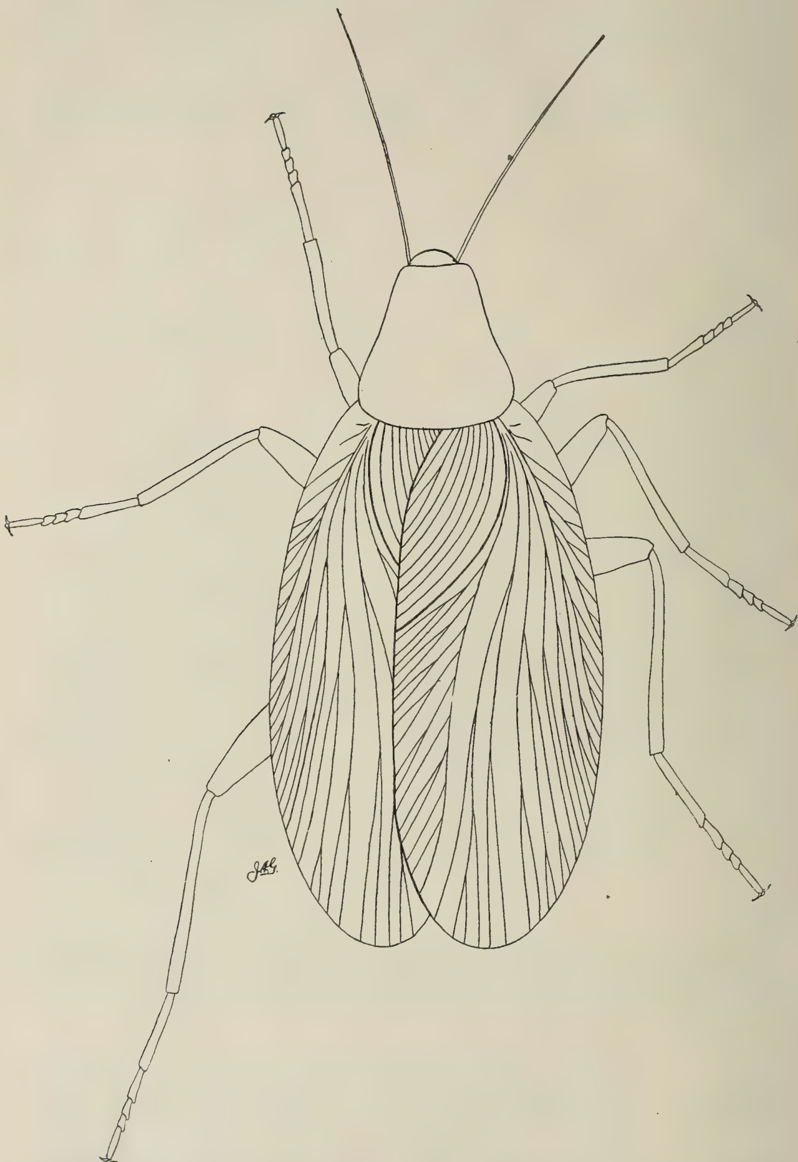


FIGURE 32.—Restoration of *Archoblattina Beecheri* Sellards; natural size.

The most distinctive character of this genus of huge cockroaches is the large, nearly rectangular pronotum, broadest at the base, and with sides and anterior border slightly emarginate. The abdomen is seen indistinctly through the wings; it is large and indicates a bulky body. The length from the front of the pronotum to the tip of the wing is 9^{cm}, making this probably the largest cockroach known. The tips only of the hind wings are seen. Apparently they are of about the same extent as the front wings. The large hind wing from the same locality, described as *Blattina* sp. by Scudder, is here provisionally referred to this species. If this reference is correct, the hind wings are very broad, with much rounded inner border.

The half-tone illustration accompanying the original description of the species was made from the mould of the dorsal surface. The figure given here is taken from the counterpart, in which the outline of the abdomen is more distinct. The two pairs of wings considerably overlap the broad abdomen. The life-size restoration is made from the specimen figured. The antennæ and legs are reconstructed from related genera. The position adopted is based upon an instantaneous photograph taken for this purpose, of the common oriental cockroach, while running. As represented in the restoration the first leg on the left side has just been thrown out in front, the second on the right side is in motion, while the third on the left is just ready to be drawn forward. The other set of three are, for the instant, supporting the weight of the body. It is not known whether the tibiæ of the genus are supplied with spines. These features are, therefore, omitted from the restoration (Figure 32).

Formation and Locality.—Coal Measures, Mazon Creek, Illinois. Type in the Yale University Museum.

Hind Wings not in connection with Front Wings.

The difficulties of nomenclature met with in the systematic treatment of the nymphs of fossil cockroaches are again encountered in dealing with such detached hind wings as lack sufficient characters to identify them with their respective front wings. Several well-marked types of hind wings, presumably representing at least as many species, have been recognized in the collections studied, three of which can be identified with the front wings. The hind wings of *Spiloblattina maledicta* have been described above in connection with the tegmina of that species. The hind wing of *Promylacris rigida* (Figure 36) is taken from the type specimen (No. 38045, U. S. Nat. Mus.). It is of special interest as revealing the form and

venation of the hind wing of the Mylacridæ. The wing is narrowed at the base, the costal border being nearly straight or a little concave at this point. The inner border although not complete is evidently rounded, and the apex obtuse. The most interesting feature of the wing is the position of the costa, which is some distance from the margin and gives off a thin superior branch. The subcosta is a stronger vein, but has only one offshoot. The radius is more developed; it divides into two nearly equal parts near the base, both of which are compound, the ultimate divisions supplying the border from the termination of the costa to the apex. The media also divides into two compound, nearly equal divisions close to the base, the branches running to the apical border. The cubitus gives off a few inferior branches which curve regularly to the border. Only a small part of the anal area is preserved. The wing just described is the left wing of the specimen. The costa of the right has two thin superior branches. The radius differs in the detail of its branching; the first and second offshoots of the lower division of the main vein are united for a short distance at their base, making a single forked branch instead of two simple branches. Length of the wing, 24 or 25^{mm}; breadth, 11 or 12^{mm}.

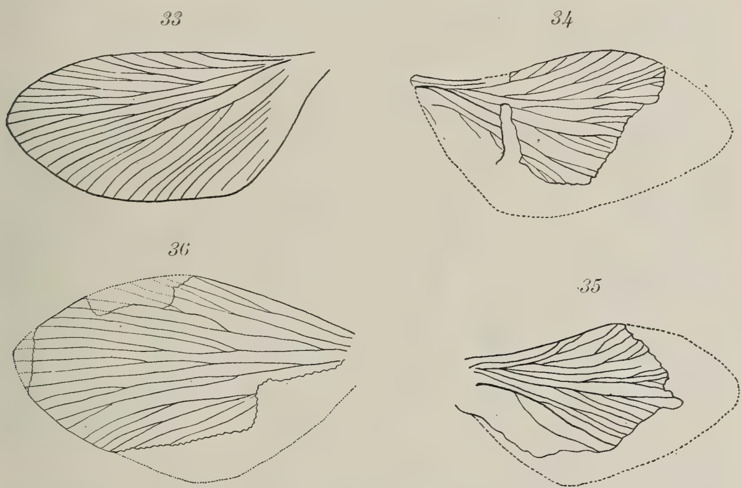
Formation and Locality.—Middle or Lower Coal Measures, Mazon Creek, Illinois.

The type of hind wing most abundant in the Lawrence Shales is that illustrated in Figure 33. There are nine specimens of the species, all conforming closely to a common type. The wings are uniformly ovate. The inner border is full and rounded. The costa is straight, simple, and reaches about one-fourth the length of the wing. The subcostal area is, as usual, in the hind wing, narrow and of slight extent. A few thin superior branches are given off from the main vein beyond the extremity of the costa. The radial area reaches nearly to the apex and has about four forked branches. The median area is large and fills the apex. The cubitus has several very oblique, simple, parallel branches. The few anal veins are parallel and usually simple, longer and more curved than in *Spiloblattina maledicta.* The wings are all of a brownish color. The species doubtless belongs to the genus *Etoblattina*, as the wings are of the ovate type, with full inner borders, thus resembling other species of that genus. Length of wing, 18 to 20^{mm}; width, 9 to 11^{mm}.

Formation and Locality.—Upper Coal Measures, Lawrence, Kansas.

Another species, the generic reference of which is doubtful, is represented by three specimens. The wing is contracted at the base and has an unusually narrow attachment. The costal

border near the base is quite concave, and the wing otherwise shows evidence of a specialized condition. The subcosta, radius, and media are united for some distance from the base. The first to separate is the media, which occupies a comparatively narrow area, branching first about the middle of the wing, its divisions running to the apex. The radius then separates from the subcosta 5 or 6^{mm} from the base, and reaches almost to the apex. The subcosta has only a few thin superior branches. The cubitus has the typical, very oblique, mostly simple veins. The anal area is long and has a few curved, forked, and rather loosely placed veins. Length, about 17^{mm}; width, 9 or 10^{mm}. Figures 34 and 35.



FIGURES 33–36.—Hind wings. Figure 33, *Etoblattina* sp.; Figures 34 and 35, undetermined; Figure 36, *Promylacris rigida*, from the type specimen; all twice natural size. Originals of Figures 33 and 35 in University of Kansas Museum; of Figure 36 in the National Museum.

Formation and Locality.—Lawrence Shales, Upper Coal Measures, Lawrence, Kansas. Types in the University of Kansas collection.

General Considerations.

The cockroaches have proved themselves a remarkably persistent type. They are known to range in time from the Middle Carboniferous to the present, and doubtless took their origin somewhat earlier. The Carboniferous representatives, as described above, were in many respects much like their modern descendants. The body had, as Scudder has well said, essentially the same shape. The legs indicate the same habit

of locomotion. The pronotum was as characteristic a feature of the Carboniferous as of the recent cockroaches, and formed quite as secure a protection for the small inflexed head. The front wing had a similar arched form, and the anal area was as well defined. Nevertheless, a closer inspection of the successive types reveals the fact that the group has by no means remained stationary throughout its long existence, but, like other organisms, is subject to the laws of advance and specialization. As will be gathered from what has preceded, the most marked changes from paleozoic to recent times have been in the structure of the framework of the front and hind wings, as well as in the abdomen and the ovipositors, and are thus in accordance with the general rule of change from the simple to the more complex, or from the generalized to the more specialized condition. In the front wings the tendency has been toward a reduction of the main veins by fusion of one or more of them. The main veins of both wings have approached more closely to the costal border. These changes have been accompanied by a less uniform development of the main veins and their branching systems. The hind wing has acquired a longitudinal, and in a few genera a transverse fold, and in most genera a fan-like plaiting of the expanded anal area. Numerous and comparatively strong cross veins, rare in the front wings, and unknown in the hind wings of paleozoic forms, have now become very commonly developed in both wings. Not only have both wings departed more widely from the primitive type, but differentiation between the front and hind wings has increased as well.* The front wings have become, as a rule, more resistant, although there were species in the Carboniferous with wings more opaque than some of the thin-winged living species. Important changes have occurred in the abdomen. The terga and sterna have been modified, tending toward a reduction in the number of abdominal segments. The genital pouch has been perfected, and the ovipositors have become reduced and adapted to perform a specialized function.

The division into coördinate groups, based originally on the differences in the venation of the front wings, was strengthened by the discovery of a well-developed ovipositor in paleozoic forms. More complete knowledge of the second pair of wings brings out additional distinctive characters. In the meantime, forms more or less intermediate are coming to light, and it may be confidently expected that the late paleozoic and early mesozoic will in time yield other intermediate forms. The exact point of disappearance of the Paleoblattidæ and origin of the Blattidæ is at present unknown. The geological age of the Fairplay deposits in South Park, Colorado, which contain the latest forms of the one in association with the earliest of the other,

* See also, Scudder, Mem. Boston Soc. Nat. Hist., vol. iii, p. 31, 1885.

has not been entirely established. Lesquereux, on the evidence of the flora, referred the deposits unhesitatingly to the Permian. Scudder, from a study of the insects, insisted on the Triassic age of the beds. The plants were found to represent several characteristic paleozoic genera. The insects belonged to eight genera, seven of which were cockroaches. Three of the cockroach genera were otherwise known only in the paleozoic, the remaining genera were new and at that time peculiar to the locality. It may not be out of place to add in this connection that the range of cockroach genera, as understood at the present time, is much less contradictory to the evidence drawn from the plants than was supposed when the papers in question were written. Five of these seven cockroach genera are now known to occur in the Coal Measures and Permian, leaving only two peculiar to the Fairplay locality and of Triassic affinity. In view of the occurrence as low down as the Coal Measures of the advanced genus *Schizoblattina*, described above, it would not be surprising to find true Blattidæ as early at least as the Permian, and should the fossil here tentatively identified as an egg case, prove to be such, it must be accepted as evidence of the existence of Blattidæ along with Paleoblattidæ as early even as the Upper Coal Measures. Of the Paleoblattidæ, the Mylacridæ will doubtless be found the older. The broad pronotum with but slightly rounded posterior border, the greater distance of the subcosta from the costal border, and the presence of a branched submarginal costa in the hind wing, all indicate the earlier position of this tribe. The Blattinariæ, on the contrary, are more diversified, continue later, and lead up to more advanced types.

In the course of their development, the cockroaches afford illustration of laws of evolution which may be summarized under the headings: Specialization by reduction; parallel evolution; mechanical principle of evolution; and recapitulation of ancestral characters.

Specialization by Reduction.—The long ovipositor of early cockroaches seems to indicate that a well-developed ovipositor is a primitive character in the Orthoptera, its reduction in the modern Blattidæ being an expression, like the peculiar egg case and genital pouch, of a specialized condition of the external genital organs. In this respect the Gryllidæ and Locustidæ present, no doubt, a closer approximation to the early condition than do the cockroaches, although on the whole the latter seem to be the more generalized. The more or less complete fusion of two or more of the main veins at their base or throughout a part of their course appears to be a second illustration of the law of specialization by reduction.

Parallel Evolution in the Orthoptera.—The plication, so constant a feature in the hind wings of modern Orthoptera, is,

as Scudder maintained, a comparatively recent acquisition. It is to be noted that the plaiting as well as the fold of the hind wing of cockroaches developed subsequent to the differentiation of these insects as a distinct phylum. A comparatively broad anal expanse was, however, common to the early Orthoptera, but the plaiting itself has originated independently in more than one division of the order. The same is true of cross veins. It is probable that at the time cockroaches were differentiated, well-marked cross veins were entirely lacking. Now, on the contrary, cross veins are numerous and not unlike those of other Orthoptera.

Mechanical Principle.—The plications are doubtless developed largely in response to mechanical need. Mechanical principles seem also to have had an influence in developing cross veins.* The interchange of the circulating fluids of the wing, tending to follow within established paths, probably also influenced the development of cross veins.

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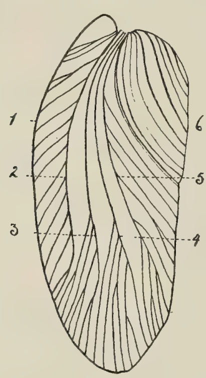

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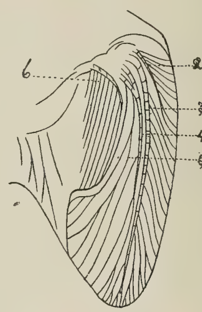

FIGURE 1.—*Gerablattina arcuata* Sellards; illustrating venation of a typical Carboniferous adult cockroach wing.
FIGURE 37.—Wing of a recent nymph; showing venation. (After Packard.)

Recapitulation of Ancestral Characters.—The recurrence during the ontogeny of the individual of characteristics found in the adult condition of earlier representatives of the phylum is familiar to the student of any group. The insects are not an exception to the general rule. In the accompanying figures the nervation of the wing of a modern nymph cockroach is brought into comparison with a typical Carboniferous adult.

*It is interesting to notice an analogous progressive evolution in the vegetable kingdom. The Carboniferous flora contains a great majority of simple veined leaves, while at the present time netted-veined leaves predominate. In the case of plants, both mechanical and physiological factors have doubtless operated.

Homologous veins bear the same number. The close similarity is very apparent. The modern cockroaches thus present in their ontogeny an interesting illustration of the recapitulation of ancestral characters.

EXPLANATION OF PLATE I.

FIGURE 1.—*Mylacris elongata* Scudder. An adult, slightly enlarged. Same specimen as illustrated by Text-figure 8. The head projects in front of the pronotum. The abdomen is noticeably short in comparison with the thorax and long wings.

FIGURE 2.—*Etoblattina mazona* Scudder. Nymph with ovipositor preserved. Same specimen as Text-figure 13.

FIGURE 3.—*Mylacris* (*Dipeltis*) *diplodiscus* Packard, sp. Type specimen. The head projects from beneath the pronotum. The impressions of the first pair of legs are indistinctly seen through the integument. The femora of the second pair of legs can be detected in the photograph. For a line drawing of the specimen, see Text figure 4.

FIGURE 4.—*Etoblattina Hilliana?* Scudder.

FIGURE 5.—*Spiloblattina maledicta* Scudder. sp. The wing shown in this photograph, also in Text-figure 26, is of the form or variety of the species with arched costal border and short cubital area.

FIGURE 6.—*Spiloblattina maledicta* Scudder, sp. Typical wing of the species having slightly arched costal border correlated with great extent of the cubitus. Same as Text-figure 27.

FIGURE 7.—*Gerablattina arcuata* sp. nov. Type specimen. The wing, as the photograph shows, has light and dark areas similar to those of *Spiloblattina*, to which genus possibly the species should be referred. The same specimen is illustrated by Text-figure 1.

FIGURES 8, 9.—*Etoblattina* sp. Detached hind wings. Same specimens as Text-figures 34 and 35.

FIGURE 10.—*Spiloblattina maledicta* Scudder, sp. The hind wing is of thinner texture and has color area similar to those of the front wing.

FIGURE 11.—*Etoblattina coriacea* sp. nov. Same as Text-figure 29.

Figure 1 is but slightly enlarged; Figure 3 is a little less than twice natural size; all others are enlarged approximately two and one-half diameters.

Figures 1-4, from the Coal Measures of Mazon Creek, Illinois; all others from the Upper Coal Measures of Lawrence, Kansas.

Originals of Figures 1, 2, and 4, in the Yale University Museum; of Figure 3, in the National Museum; all others, in the University of Kansas Museum.

ART. XXVII.—*Electrotropism of Roots;* by AMON B. PLOWMAN. (With Plates IX and X.)

IN a brief report published in this Journal last month, the writer gave the more important results of a series of experiments in the field indicated by the above title. These observations extend over a period of more than two years, and have been carried on as a part of a general study of the electrical relations of plants, at the Memorial Research Laboratory of Harvard University. As indicated in the preliminary paper, this particular phase of the work has had for its object the explanation of the behavior of roots growing in the presence of an electrical current.

The general fact of galvanotropic response in roots was established in 1882 by the careful studies of Elfving,* who found that the roots of young seedlings growing in spring-water through which a current of electricity was flowing, almost invariably turned, after a little time, toward the positive electrode. Elfving modified his experiment by using from one to six Leclanché cells in his battery; by varying the distance between electrodes from 2·5^{cm} to 15^{cm}; by the use of zinc, copper, platinum, and carbon electrodes; and by a study of various plants, including species of *Vicia*, *Zea*, *Secale*, *Hordeum*, *Cannabis*, *Ricinus*, *Cucurbita*, *Tropaeolum*, *Convolvulus*, *Cynara*, *Helianthus*, and several others. He found that throughout all these variations in conditions the results remained practically constant in kind, the roots always turning, sooner or later, toward the positive pole. He observed, also, that the roots were invariably killed by the prolonged action of the current from even a single Leclanché cell.

By way of explanation of his results, Elfving showed that the elongation of a root in the presence of an electric current is approximately only half as great in a period of 12 hours as is that of a similar root growing under normal conditions for the same length of time. Hence it was evident that growth was retarded by the electric current, and the greater retardation on one side than the other of the root was attributed to some unknown property of the root itself. This view of the matter was apparently fully justified by certain results obtained by Elfving in his trials with seedlings of *Brassica* and *Raphanus*. In the former the majority of the roots turned toward the negative pole, while in the latter there was no well defined response in either direction. This would indicate a specific difference which could be attributed only to the protoplasm itself, and it was upon this difference that Elfving proposed to separate plants into two groups, the one positively galvanotropic, the

*Bot. Zeit., 1882.

other negatively galvanotropic. It should be stated, however, that in the earlier part of his paper Elfving observes that galvanotropism is not to be considered a biological phenomenon of the same order as heliotropism, geotropism, and most other common paratonic responses. In accounting for the invariably fatal effects of a long-continued current, Elfving offers the suggestion that the electrolyte is probably rendered toxic by the formation of poisonous compounds at the surface of the electrode.

While Elfving's study of this subject was quite complete and his methods were in general above question, it has seemed desirable not only to repeat his work, but to extend it in a number of lines, in order, if possible, to arrive at some more satisfactory explanation of the results obtained.

The electrical equipment used for these and related studies consists of a battery of "Excelo" cells, a small direct-current dynamo, the 500-volt city power current, and various resistances, rheostats, and measuring instruments. The "Excelo" cell is a combination of the principles of the Daniell cell and the "gravity" cell. This cell is very satisfactory for closed-circuit work, since it maintains a practically constant potential for days or even weeks, especially when only a fraction of the available amperage is used. The dynamo is of the General Electric type, driven by a General Electric 500-volt direct-current motor. The dynamo is rated at 2·5 kw. capacity, at a voltage ranging from 75 to 125 at normal speed, controlled by a field rheostat. A speed-rheostat on the motor permits a considerably wider range of voltage in the dynamo. The 500-volt power-current itself is available for experimental work, through a series of resistances and rheostats. Among the measuring instruments are included a watt-meter, volt-meters, ammeters and galvanometers, one of which is sensitive to 10^{-6} volt. It is possible to obtain from this equipment a fairly complete gradation of measured initial potentials from 500 volts down to 10^{-6} volt.

However, it is not always sufficiently explicit to state merely the difference in potential between the terminal electrodes, since the amount of the current, which is the essential thing, depends quite as much upon the form and conductivity of the electrolyte as upon the initial potential-difference between the electrodes. In other words, it is the density of the current which is of importance in our present investigation. Current density has been variously defined by different authorities,* but it is sufficiently definite for our purpose to consider current

* A. Gray, "Absolute Measurements in Electricity and Magnetism," p. 7, 1888. Oliver J. Lodge, "Modern Views of Electricity," p. 69, 1889. W. E. Ayrton, "Practical Electricity," p. 117, 1887. Clerk Maxwell, "Electricity and Magnetism," § 64, 1881.

density as the amount of current passing a unit cross-section of the conductor in unit time. This, in any case, will evidently depend upon the E.M.F. of the current, the conductivity of the conductor, and upon its sectional area and the distance between electrodes. The unit of current density is the milli-ampere, and the current is of unit density when the conditions of the circuit are such that one milli-ampere of current passes 1^{cm^2} of sectional area of the conductor in one second.

The general method of experimentation has been similar to that followed by Elfving. Fig. 1 (Plate IX) shows one of the vessels used in subjecting roots of seedlings to the action of an electric current. Internally this vessel measures about 5^{cm} wide, 15^{cm} long, and 18^{cm} deep. When in use the cubette is wrapped with black paper in order to protect the roots from the influence of light. In the majority of cases the electrolyte employed has been ordinary tap-water, though as one phase of the study, dilute solutions of a great variety of substances were used. Since the products resulting from the electrolysis of common metallic electrodes such as copper, zinc, tin, etc., are usually highly injurious to plants, it was found necessary to use electrodes of platinum or carbon. The latter material has proved to be entirely satisfactory, and it is to be recommended for its cheapness and convenience. In the small vessel shown in fig. 1, the electrodes are "Electra" arc-lamp carbons, $\frac{5}{8}'' \times 7''$, fitted with binding-posts for connecting the wires. In a larger vessel plate carbon electrodes were used. These were of high-grade carbon, $\cdot6^{cm} \times 4^{cm} \times 15^{cm}$, each with a binding-screw. It has been shown by repeated experiments that the product of electrolytic decomposition of these carbons is perfectly harmless to plants, even when present in sufficient amount to render the electrolyte quite black.

The seedlings are suspended by glass hooks passing through a sheet of cork which serves as a cover for the vessel. In this way perfect insulation is secured, thereby preventing any passage of current through the root in the direction of its longer axis.

The seeds are first germinated in moist sphagnum, and when the radicles have reached a length of 2^{cm} to 4^{cm}, the seedlings are attached to the glass hooks with their roots pointing directly downward and dipping a short distance into the water in the jar. If left to grow normally in such a situation, some roots will grow directly toward the bottom, while others bend about in a more or less tortuous path. It is a well-known fact that different species of plants show characteristic behavior in this respect. Thus *Pisum sativum*, many varieties of *Zea mais*, and various other plants develop quite crooked roots when grown in water, while other varieties of *Zea mais*, *Lupinus albus*, *Hyacinthus orientalis*, etc., grow long straight roots under these circumstances.

However, if a current of electricity be passed through the

water in which these roots are growing, they almost without exception turn, sooner or later, toward the positive pole. The time required for this reaction depends upon the kind of plant, as well as upon the density of the current. In a uniform current, those plants which show most rapid normal growth of the roots are the ones which show a typical curvature most quickly. For any given kind of root there is a maximum current density at which the curvature is produced most rapidly, while a weaker current requires a longer time to bring about the same results. On the other hand, if the current density be raised even slightly above the specific maximum, the roots are killed before curvature can take place. As is to be expected, this specific maximum differs considerably in different plants, and also for roots of different degrees of maturity in the same plant. Thus the maximum effect is produced in a radicle 2^{cm} long of *Lupinus albus* by a current density of about 1 milli-ampere, while a similar root of *Zea mais* reacts most rapidly in a current of 1·5 milli-amperes. For roots which have reached a length of 12^{cm} or 15^{cm} the maximum current density is less than for the shorter roots, being about ·8 milli-ampere for *Lupinus* and 1 milli-ampere for *Zea;* and the maximum curvature is less rapid than in the case of young roots.

The abruptness of the curvature is dependent chiefly upon the kind of plant and the vigor of the root, but, other things being equal, it appears that the sharpest curves are formed in a current considerably below the specific maximum density. It frequently happens that roots of *Zea mais* are curved through an angle of 90° in a length of 1^{cm} or less, and very young radicles of *Lupinus albus* have been bent through a right angle in a length hardly exceeding twice the diameter of the organ at the middle point of the curve.

Fig. 2 represents a number of young seedlings of various size of *Zea mais*, after being exposed for one hour to a current density of 1·2 milli-amperes. The sharpest curvature in this case is shown by the shortest of the radicles, while the longer ones show a more gradual bending. If a weak current is kept on such seedlings as these for several hours, it is found that the majority of the roots continue to grow horizontally toward the positive pole. The maximum current density invariably kills the roots in a short time, as was observed by Elfving, but it has been found possible to adjust the current to such a strength as not to kill the roots and yet to hold them to their horizontal course against their normal geotropic tendency.

On the other hand, if the current is turned off after an hour, and the seedlings are left in the water for a time, we often obtain such results as those shown in fig. 3. Here most of the roots have continued to curve, in some cases forming complete coils. It has often happened that roots which have been less seriously affected than those shown in fig. 2 will, when removed

from the action of the current, bend downward again near the tip, forming a double curve, and continuing to grow in an altogether normal way again. In such cases there is always developed a conspicuous enlargement of the root at the second, or lower, curve, and a constriction at the first, or upper, one. This constriction is always in the form of a flattening of the concave side of the curve.

The location of the greatest curvature in the root is, as Elfving observed, at the point of most rapid normal elongation. It should be added, however, that the sharpest part of the curve is at the point of most rapid elongation at the time when the current is first turned on. This fact is most strikingly evident in the case of very vigorous roots exposed to a rather weak current. In long roots which are exposed for their whole length to the current, there is but little curvature in the piliferous zone. Hence it appears that the curvature is dependent upon active growth of the cells.

When the seedlings are suspended so that the root-tips just touch the water in the jar, the curvatures are usually different from those developed when the roots are wholly submerged, and the reaction varies more noticeably with change in amount of current. For example, if seedlings of *Lupinus albus* are arranged with roots dipping 1^{mm} or less into the water, and a very strong current, say 10 milli-amperes, is passed for a few minutes, the root-tips soon curl to such an extent as to be lifted out of the water. In a few instances the roots have continued to grow horizontally for several millimeters just above the surface of the water, and toward the positive pole, but they are usually killed at once by a current of this density. With a very weak current the roots do not commonly begin to curve perceptibly until the zone of most rapid elongation reaches the surface of the water, when a prompt response occurs, just as in the case of wholly submerged roots.

When the seedlings are placed with their roots horizontally, or parallel to the path of the current, those which point toward the positive pole continue to grow in that direction, contrary to the influence of the force of gravity, so long as the current is comparatively weak. A stronger current quickly kills these roots, though without producing any curvature in them. The roots pointing toward the negative pole usually bend downward in a perfectly normal manner for a little time, then the curvature becomes very abrupt, and the tips are turned back toward the positive pole. If the current is turned off at this stage, the roots sometimes continue to bend, forming a complete coil, and then growing downward again. It usually happens, however, that the seedlings are killed by this treatment.

Elfving has shown that when an electric current is passed upward through a root the cells are quickly killed, while other roots transmitting a similar current downward are not seriously

affected, even after several hours. This experiment was repeated by suspending two seedlings by hooks of platinum wire, with the roots dipping several millimeters into a vessel of water. The platinum wires are connected through a resistance with the battery, making a circuit downward through the first root, and upward through the second. Under these conditions a ·1 milliampere current killed the second root in twelve hours, while the first was not apparently affected. When a ·5 milli-ampere current was passed through the roots for half an hour and then turned off, the second root was greatly checked in its growth, and after a few hours it showed a pronounced bending toward the other root. In every case the prolonged passage of even a very weak current caused a loss of turgor in the parts of the first seedling in the region of the platinum contact, even when the root itself was unaffected.

In comparing the results of these studies with those given by Elfving, it appears that there is substantial agreement in the general fact of response curvatures. The plants examined include practically all those enumerated by Elfving, with the addition of species of *Lupinus*, *Linum*, *Fagopyrum*, *Milium*, *Allium*, and *Hyacinthus*. However, it has been shown that the passage of an electric current through water in which seedlings are growing is not necessarily fatal to the plants, as asserted by Elfving, but that the current may be so weak as not to kill the roots and yet cause them to grow horizontally toward the positive pole.

Moreover, the so-called "negative galvanotropism" mentioned by Elfving does not seem to be a constant property of any species thus far studied. That the usual curvature toward the positive pole is less pronounced and less constant in some species than in others, can not be denied. However, the reverse curvature has not been found to be constant in any case, and even in the most doubtful species it has been possible, by varying the density and time of action of the current, to produce the normal curvature in a majority of the roots.

That Elfving was justified in concluding that galvanotropism is not of the same order of phenomena as heliotropism, geotropism, hydrotropism, etc., is made apparent by the facts just pointed out. The great rapidity of the reaction under certain conditions, and the fact that all but extremely weak currents are very harmful to the plant, seem to indicate the same conclusion. But it must be admitted that so far as the real significance and ultimate explanation of the phenomenon are concerned, no satisfactory solution is offered either by mere external appearances or by the purely biological features of the case.

A comparative study of the internal structure of normal and electrically curved roots has proved highly instructive in this connection. Fig. 4 shows a longitudinal section of the tip of a root of *Hyacinthus orientalis*, which had been acted upon for

half an hour by a current of ·8 milli-ampere density. The side of the root represented by the left-hand side of the figure was directed toward the positive pole. Here the cells are evidently in a state of partial collapse, the protoplasm is contracted, and the thin walls are more or less crushed. On the opposite side of the root there is every indication of a perfectly normal condition of the cells. Fig. 5 is from a longitudinal section of a root of *Hyacinthus orientalis*, after three hours exposure to a ·7 milli-ampere current. This section is taken from a part of root about 14^{mm} or 15^{mm} back of the tip, or at the point where elongation was most rapid at the time when the current was first turned on. It is perfectly evident that the cells on the concave side of this root, or the side toward the positive pole, were killed, while those on the opposite side kept on growing quite normally.

It should be mentioned in passing that when such curved roots are fixed in Flemming's fluid there is always a conspicuous white stripe down the concave side of the root, even after the other parts have turned quite brown or even black. This is an indication of the presence of dead cells in this region. The same thing is often shown in roots while the electric current is still acting upon them, by the fact that the concave side of the root becomes translucent from the escape of cell-sap into the intercellular spaces.

The harmful effects of the current are even more strikingly shown in cross-sections of the curved roots. Fig. 8 represents a transverse section at 10^{mm} from the tip of the root of *Hyacinthus orientalis*, after exposure to a ·7 milli-ampere current for one hour. Here the upper left-hand part of the section was directed toward the positive pole. Fig. 9 is from a section of such a root after two hours action of a similar current. In this case the upper right-hand side was toward the positive pole. Fig. 10 is an enlarged view of a part of the section shown in fig. 9, along the line between the more affected and the less affected parts. A comparison of these with fig. 6, taken from a section of a normal root, shows that there has been more or less shrinkage and collapse in all parts of the curved roots, but that the actually destructive action has been confined to the side toward the positive pole. This partial collapse of the entire structure is not evident in a root exposed to a ·1 milli-ampere current, while a very brief action of a strong current produces this effect in the entire root-tip, as shown in fig. 7, which is from a section of a root of *Hyacinthus orientalis*, treated for five minutes with a 10 milli-ampere current.

From these facts of the minute anatomy of electrically curved roots it seems to be self-evident that the curvature is the result of the paralysis and death of the protoplasm on one side of the structure, resulting in the complete arrest of development in that region, while the other parts go on growing in a more or

less perfectly normal way. As suggested in a former report,* this condition of the root is most satisfactorily accounted for by attributing the effects upon the protoplasm to the direct action of the positive electrons. That the effects are not of an ordinary chemical nature is evidenced by the fact that, so far as is known, the nature and rapidity of the response is conditioned solely upon the density of the current, regardless of the chemical composition of the electrolyte. This conclusion is based upon the results of large numbers of trials with a great variety of acids, bases, and salts, used always, of course, in extremely dilute solution, but giving, nevertheless, a wide variation in the chemical nature of the positive ions. But so long as the current density is kept constant the roots behave in precisely the same manner, regardless of the chemical composition of the electrolyte, provided always that the chemicals are so dilute as not to be directly and immediately harmful to the plants.

Upon the basis of the electron theory all the phenomena of electrotropism are readily and naturally explained. Whenever an electric current flows through an electrolyte, there is a stream of positive electrons flowing from the positive pole to the negative pole, while an equivalent stream of negative electrons flows toward the positive pole. Any object, such as the root of a seedling, dipping into the electrolyte parallel to the electrodes, will have that side toward the positive pole exposed to the stream of positive electrons, while the other side is equally exposed to the negative electrons. Consequently the cells on the side of the root toward the positive pole are sooner or later killed by the positive electrons, while the other side of the root continues to grow more or less vigorously, pushing the tip of the root around in the direction of the positive pole. When the growing end of the root has reached a horizontal position, or has become parallel to the streams of electrons, it is kept in that position, since any deviation would expose the more rapidly growing side to the positive electrons, with a consequent checking of the growth and a return to the horizontal position. The same explanation holds good in the case of roots which are placed originally in the horizontal position with their tips pointing toward the positive pole. That the delicate growing point is not at once killed when thus directed against the destructive stream of electrons is no doubt to be accounted for by the presence of the root-cap, which more or less effectually shields the meristematic tissue for a time at least.

Similarly we may explain the behavior of the seedlings used as electrodes. The positive one is injured only at the point of contact of the platinum wire, where the positive charge enters it. The part dipping into the water is receiving a stream of negative electrons, and consequently is uninjured. The negative seedling, on the other hand, is receiving a stream of posi-

* See this Journal, vol. xiv, p. 131, 1902.

tive electrons through its root, chiefly from the side toward the other seedling, hence it is curved and ultimately killed.

So far as can be made out from these studies up to the present time, the negative electrons are in no case harmful to plant protoplasm; and in several instances a marked acceleration in growth may reasonably be attributed to their influence. However, in the present state of knowledge, it would be imprudent to assert without qualification that negative electrons stimulate vegetable protoplasm.

A study is now being made of the effects of electric light and power-currents upon trees growing near to or in contact with the conductors. The facts thus far collected are in perfect accord with those outlined in this paper.

For the present, the point of principal interest lies in the fact that the phenomenon termed "galvanotropism" by Elfving has its ultimate cause in the effects of the electrons, or electricity *per se*, and apart from any streaming of ions or any ordinary chemical reaction. It is for this reason that the term "electrotropism" is deemed more appropriate than the term "galvanotropism" as used by Elfving.

Aside from their purely biological relations, the results of this investigation are of interest in their bearing upon the theory of ionization and upon the electron theory. For every new problem that is satisfactorily solved by a theory renders that theory more credible; and the problem of electrotropism is certainly of this nature, in its relation to the theories mentioned.

The results of these studies seem to indicate that whatever advantages may be derived from the use of electricity in practical horticulture are to be attributed rather to secondary chemical and thermal effects than to electrical energy as such, except perhaps in cases where the plants are negatively charged.

Harvard University, July, 1904.

EXPLANATION OF THE FIGURES, PLATES IX AND X.

Fig. 1. Cubette jar, with electrical connections, for subjecting roots of seedlings to the action of an electric current. (x $\frac{1}{6}$.)

Fig. 2. Young seedlings of *Zea mais*, after exposure for one hour to the action of a weak current. (x $\frac{1}{3}$.)

Fig. 3. Young seedlings of *Zea mais* which were exposed to the action of an electric current for one hour, then left in the water for an hour without current flowing. (x $\frac{1}{3}$.)

Fig. 4. Longitudinal section of a root-tip of *Hyacinthus orientalis*, which had been subjected to the action of an electric current for thirty minutes. (x 75.)

Fig. 5. Longitudinal section of a root of *H. orientalis*, showing the effect of three hours action of the electric current. (x 75.)

Fig. 6. Transverse section of a normal root of *H. orientalis*, 8^{mm} from the tip. (x 75.)

Fig. 7. Transverse section of a root of *H. orientalis*, 8^{mm} from the tip, after exposure for five minutes to a very strong current. (x 75.)

Fig. 8. Transverse section of a root of *H. orientalis*, 10^{mm} from the tip, showing effect of a moderate current acting for one hour. (x 75.)

Fig. 9. Transverse section of a root of *H. orientalis*, 12^{mm} from the tip, after exposure for two hours to a moderate current. (x 75.)

Fig. 10. A part of fig. 9 more highly magnified. (x 350.)

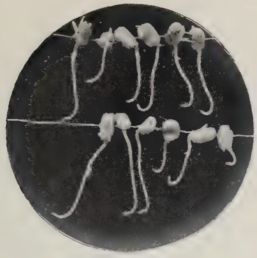

Fig. 2.

Fig. 3.

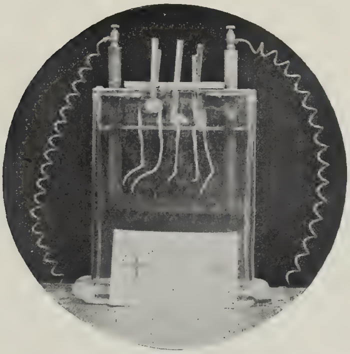

Fig. 1.

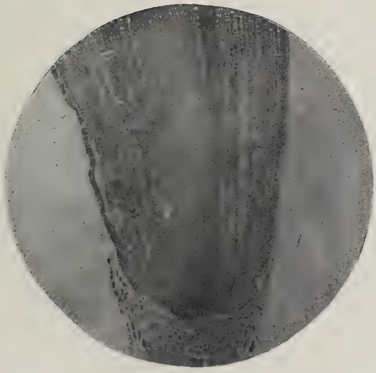

Fig. 4.

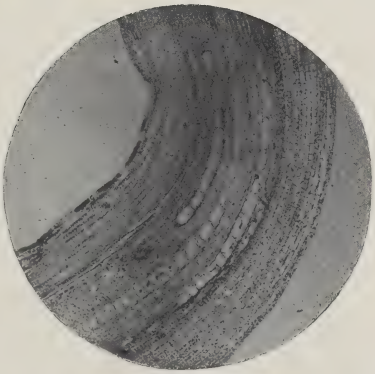

Fig. 5.

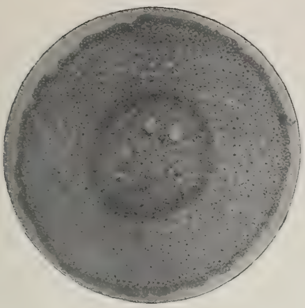

Fig. 6.

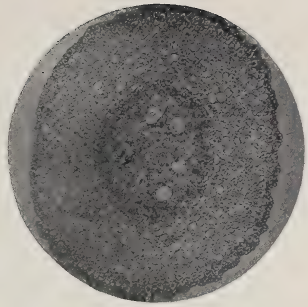

Fig. 7.

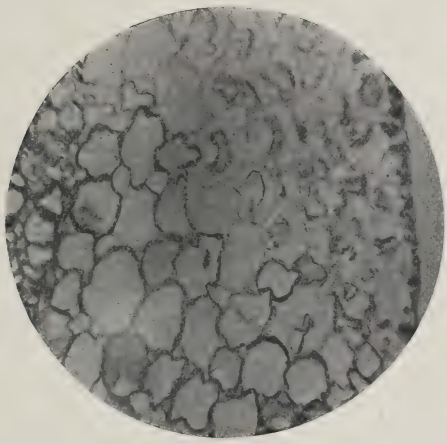

Fig. 10.

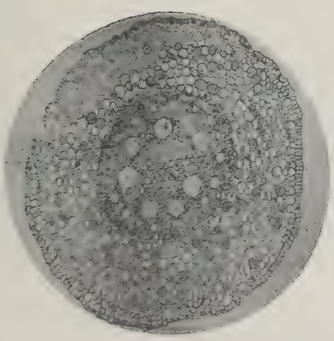

Fig. 8.

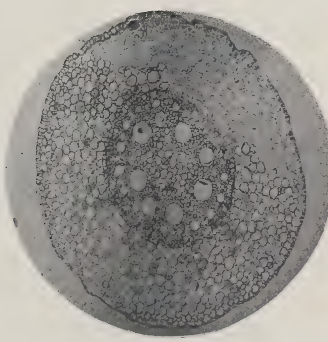

Fig. 9.

SCIENTIFIC INTELLIGENCE.

I. Geology and Mineralogy.

1. *United States Geological Survey.*—The following publications have recently been received:

Professional Papers No. 21.—Geology and Ore Deposits of the Bisbee Quadrangle, Arizona; by E. L. Ransome, 162 pp., 29 pls., 5 figs.—The lowest rocks of the Bisbee district are pre-Cambrian schists derived from arkose sediments and separated from the overlying Paleozoic beds by a profound unconformity. Cambrian quartzite, 4500 feet of limestone belonging to Cambrian, Devonian, and Carboniferous time, and 4500 feet of Cretaceous sediments constitute the strata represented. Faulting and folding accompanied by intrusions of granitic magmas and by mineralization occurred at the close of the Carboniferous. Later disturbance took place in post-Cretaceous time. The effect of intrusion of granite porphyry is inconspicuous. Faults in this region are numerous and the larger ones are located along a NW.-SE. tract about 2½ miles wide. Certain of the reversed faults are occupied by dikes intruded during the faulting. None of the workable ore deposits occur as lodes or fissure veins. With few exceptions the deposits, from which 400,000,000 pounds of copper have been taken, are irregular replacements of limestone.

No. 22.—Forest Conditions in the San Francisco Mountain Reserve, Arizona; by J. B. Leiberg, L. F. Rixon and A. Dodwell, with an introduction by F. G. Plummer, 91 pp., 7 pls.

No. 23—Forest Conditions in the Black Mesa Forest Reserve, Arizona; by E. G. Plummer from notes by L. F. Rixon and A. Dodwell, 60 pp., 7 pls.

No. 28.—Superior Analyses of Igneous Rocks from Roth's Tabellen 1869 to 1884, arranged according to the quantitative system of classification; by H. S. Washington, 51 pp. The chemical analyses of rocks published from 1884 to 1900 inclusive, are collected in Professional Paper No. 14. To this have now been added the more reliable and complete earlier analyses. The poor quality of early analytical work is made evident from Doctor Washington's selections. Analyses made previous to 1861 are discarded; of those made between 1861 and 1884 10·24 per cent are retained; and of those made between 1884 and 1900 64·70 per cent are worthy of permanent record. Of 5,303 analyses made between 1861 and 1900 inclusive, 2,112 or 39·83 per cent are classed as superior.

Bulletins. No. 224.—A Gazetteer of Texas; by Henry Gannett, 176 pp., 8 pls. As revised in the second edition the Gazetteer of Texas is a model for such work. Besides the list of place names, data are given regarding soil, climate, education, industries and other geographic elements.

No. 226.—Boundaries of the United States and of the several States and Territories; by HENRY GANNETT, 138 pp., 54 pls. The usefulness of this manual is shown by the fact that two previous editions have been exhausted. The history of all important changes of territory is given, together with a copy of the laws concerning them.

No. 229.—The Tin Deposits of the York Region, Alaska; by ARTHUR J. COLLIER, 57 pp., 7 pls., 5 figs. Tin ore probably of commercial value has been found in widely separated localities in the York region. The ore occurs in alluvial deposits occasionally traced to small veinlets in slate, and in well-defined veins of greisen associated with siliceous intrusions. Mr. Collier gives a valuable general discussion of the occurrence and method of working tin, and adds a bibliography of the subject.

No. 230.—A Gazetteer of Delaware; by HENRY GANNETT, 15 pp.

No. 231.—A Gazetteer of Maryland; by HENRY GANNETT, 84 pp.

FOLIOS. No. 101.—San Louis Folio, California, by H. W. FAIRBANKS. The Coast Ranges of California are exceedingly complex in their geologic structure and students will welcome this description of a typical area. The sedimentary rocks represented belong to Jura-trias, Cretaceous, Neocene and Pleistocene formations, and the igneous rocks, both extrusive and intrusive, date from these same periods except the Pleistocene, and there is in addition a pre-Triassic granite. The igneous varieties represented are granite, diabase, basalt, augite-teschenite, olivine-diabase, quartz-basalt, rhyolite, tuff, pyroxene-andesite, peridotite, pyroxenite, norite, gabbro, andesite-granophyre and dacite-granophyre. The Jura-trias rocks contain molluscan remains not found elsewhere on the Pacific coast. Lens-shaped bodies of jasper occur with the sandstone, and there is an abrupt change from the rock containing siliceous tests of radiolaria to the shallow water formation showing no radiolaria. Abrupt alterations of currents, or depth, or shore line, must have taken place. Lenticles of glaucophane schist from 1 foot to 100 feet in thickness are irregularly formed and ascribed to contact metamorphism. The volcanic eruptions connected with the Monterey shale (Neocene) occurred beneath the sea and consist largely of ash and pumice. The pumice has become so impregnated with pyrite as to form a very resistant rock in which shore terraces are cut. In its topographic development this region presents an interesting study of planation, stream adjustment and of development of a coast line during several periods of elevation and depression. The San Louis valley has been developed by two sets of tributary streams, while the master stream crosses the valley at right angles and enters a canyon. The Salinas is an excellent example of a superimposed stream. It flows in a granite-walled canyon parallel with and a short distance from a wide valley cut in soft rock. Numerous faults are described by

Professor Fairbanks, one with a throw of 2000 feet, yet no fault lines are shown on the map, because "not clearly defined in the field." They are shown, however, in the structure sections and it would be of advantage to students if a less conservative attitude had been adopted in constructing the areal map.

No. 107.—Newcastle Folio, Wyoming–South Dakota; by N. H. DARTON.

No. 108.—Edgement Folio, South Dakota–Nebraska; by N. H. DARTON and W. S. TANGIER SMITH.

The three folios (Nos. 85, 107, 109) which describe the geology of the edge of the Black Hills uplift are interesting, because of their local features, and because they furnish such excellent illustrations of simple monoclines, erosion forms and stream systems. They are destined to be much used in teaching.

No. 109.—Cottonwood Falls Folio, Kansas; by C. S. PROSSER and J. W. BEEDE. This quadrangle is part of the Great Plains province and is underlaid entirely by Carboniferous rock, mostly limestone. The topographic features are due to erosion of nearly horizontal strata.

2. *Geological Survey of Canada.* Summary Report for 1903. 212 pp., 7 maps.—For the year 1903 the staff of the Canadian Survey numbered 57, and Dr. BELL had at his disposal an appropriation of $133,000. Economic work has received chief attention, and parties have been at work investigating mineral resources in Yukon Territory, British Columbia, Ontario, Quebec, New Brunswick and Nova Scotia. Mr. R. W. BROCK describes the Physiography of the Lardeau District, one of the most rugged and picturesque portions of the Selkirks. Dr. R. A. DALY continued his work along the international boundary. He found the conditions exceptionally favorable for structural studies. Three master thrust faults occur. One of them lies in the plane of bedding and the blocks have been rotated and overturned. Additional evidence is found in support of the hypothesis of "overhead stoping" as a mode of igneous intrusion. The work of the survey is retarded by the lack of adequate topographic maps.

3. *Examination of the Coral-Rock Cores from the Borings at Funafuti.*—The general report upon the borings made in the coral rock of the atoll of Funafuti has already been noticed in a recent number (vol. xvii, p. 478, June, 1904); some of the results, however, which have been reached by Prof. J. W. JUDD and Dr. C. GILBERT CULLIS, in the minute chemical and microscopical examination of the cores of coral rock obtained deserve more detailed presentation. It will be remembered that the main boring was carried to a depth of 1114½ feet, while two other minor borings were also made at an earlier date. Samples from the former boring yielded 133 analyses, and those from the latter 72 analyses.

The chief result of this careful chemical work is to show that in the first 50 feet of descent there is a gradual rise in the per-

centage of magnesium carbonate up to 16 per cent; this maximum occurring at depths of 15 and 25 feet, with a falling off between these depths to 12 per cent. From a depth of 25 feet there is a gradual decline in the proportion of magnesium carbonate till 50 feet is reached, where only the normal amount of 1 to 5 per cent is present. This latter relation continues from 50 to 637 feet. From here down, however, the percentage rises rapidly, so that at a depth of 658 feet the proportion of magnesium to calcium carbonate reaches the limit of 40 to 60. This high percentage of 40 per cent is maintained to the bottom* (1114½ feet) with small variation (except for two interruptions to be mentioned), the maximum of 43 per cent being reached at 950 feet. Exceptional conditions were noted twice: between 819 and 875 feet, the proportion of $MgCO_3$ varies widely with a minimum of 4·8 per cent at 826 and a second of 20·6 per cent at 866, and a maximum of 28·5 per cent at 855 feet. Again, between 1050 and 1097 feet there is a falling off, with a minimum of 26·63 per cent at 1061 feet and 30·7 per cent at 1080 feet, and a maximum of 39·4 per cent at 1070. These wide variations remain unexplained.

In regard to other constituents in the rock, it may be briefly stated that the amount of organic matter in the samples examined was found to be extremely small; at depths below 100 feet quite inappreciable; insoluble inorganic matter was also shown to be almost completely absent, as is true in general of coral reef rocks not formed near volcanic masses. The amount of phosphates present was in all cases minute and often quite inappreciable.

The chief interest in regard to the facts stated centers in their bearing upon the important problem of the dolomitization of limestone rocks. This subject is discussed with much thoroughness by Professor Judd. Attention is called to the established fact that the amount of magnesium carbonate present in living corals is small. The greater solubility of the calcium carbonate, however, tends to increase the relative amount. The rapidity of the leaching-cut process depends upon the special conditions of temperature and pressure, and further varies widely with different organisms, being greater with those (as the algæ) in which organic matter is present to considerable amount.

This process of leaching-out seems to offer an adequate explanation of the increase in the magnesium carbonate up to 16 per cent, which as stated was observed in the upper part of the cores. The much greater rise in the proportion from a depth of 637 feet to the bottom, reaching a maximum of 43 p. c. at 950 feet, requires another explanation. Here, moreover, as shown by the examination by Dr. Cullis mentioned below, the mineralization, slight above, is prominent, the cores are fairly solid and distinct crystals of dolomite are formed to a greater or less extent throughout the mass.

The author's views can best be presented by quoting his words.

* Normal dolomite calls for 45·65 per cent.

Speaking of the mass resulting from the leaching-out of the calcium carbonate with its enrichment in magnesium, the author adds : " Now this mass in a coral reef is everywhere permeated and acted upon by sea-water containing a very notable proportion of magnesium, principally in the condition of chlorides and sulphates. May not these materials enriched by the magnesium carbonate exercise an attractive action on the magnesium salts of the ocean waters, giving rise to double decomposition and the gradual replacement of a part of the calcium in the carbonates by magnesium." . . . " It by no means follows that, because the dolomite crystals are found only at considerable depth, the action to which the formation of the crystals was due took place only at this depth. The action may possibly have taken place at or near the surface and the rock have subsided after its alteration. At the same time it may be noted that all the rocks now at short distances from the surface in Funafuti show no dolomite crystals and contain only such an amount of magnesium carbonate as may be accounted for by the leaching-out process."

The author adds in closing : " From what has been said, it will be apparent that while the investigations that have been carried on upon materials obtained in the vertical borings of Funafuti and also in specimens obtained from upraised reefs in the Indian and Pacific oceans, show that the dolomitization of coral-reef rock, first demonstrated by the researches of Dana and Silliman, really takes place sporadically over very wide areas, the exact conditions under which the operations occur still call for careful investigation both by observation and experiment."

The mineralogical changes in the cores from the Funafuti borings have been carefully investigated by Dr. Cullis and the results are described with many excellent illustrations in Section XIV of the Report. The discrimination between the three constituents of the coral rock, calcite, aragonite and dolomite, was aided by the use of methods of staining, one of which (after Meigen) served to separate the aragonite from calcite and dolomite, the other (Lemberg) the dolomite from the other species. Speaking generally, it was found that aragonite occurs in the upper cores only and dolomite only in the lower ones (below 637 feet), while calcite, which is the sole constituent of the middle cores, occurs with aragonite above and with dolomite below; aragonite and dolomite were in no case found associated.

The microscopic examination of the cores down to a depth of 637 feet shows the original rock unchanged in the first few feet only; below this point a greater or less degree of alteration has gone on. The changes noted in the first 637 feet include the deposition of secondary calcite and aragonite from solution, the former generally and the latter always in continuity with the same mineral in the original organisms; also the crystallization of the finely divided calcareous detritus and finally the gradual disappearance of the aragonite. As already stated, no individualized dolomite is found in the upper cores even where partial

dolomitization has gone on and the percentage of magnesium carbonate has increased to 16 per cent. Another point of interest is that near the surface masses of dense solid coral rock are common, farther down these are rare and between 220 and 637 feet they do not exist, the material resembling unconsolidated coral reef sand. This difference is explained by the effect of the more complete solution and removal of the original aragonite. When the original rock consisted chiefly of calcite this has been less affected by solvent action and the rock is sufficiently coherent to yield more or less solid cores; when aragonite was more prominent its removal has left the rock in a fragmental and incoherent condition.

A marked change begins with the core at 638 feet; here a large percentage of magnesium carbonate is found, making as before stated a maximum of 43 per cent at 950 feet, and with the exceptions mentioned on p. 240, this condition is maintained to the bottom mineralogically. This means that the cores consist of dolomite, in many cases in the form of distinct rhombohedral crystals, while recognizable calcite has largely or completely disappeared. A feature of the lower cores (from 815 feet down) is the presence of fibrous deposits gradually increasing in relative amount; at first this consists entirely of calcite, at greater depths of alternate layers of calcite and dolomite; in one case (1090 feet) five such layers were observed. Many interesting variations are noted in the microscopic sections in the appearance of the dolomite and calcite and their relations to each other and to the original organisms. These are clearly described and in addition are distinctly presented to the eye in the admirable series of figures, all of which deserve to be carefully studied. Enough has been said, however, to indicate the general conclusions arrived at and to show that this unique investigation serves to throw much light on some of the most difficult problems in connection with the history of the coral reef.

4. *Brief notices of some recently described Minerals.*— Bakerite is a new borosilicate of calcium described by W. B. Giles from the mines of the Borax Consolidated Company in the Mohave desert, 16 miles northeast of Daggett, San Bernardino county, California. It occurs in white, amorphous masses forming veins and nodules of considerable size. In appearance it resembles unglazed porcelain or fine-grained marble; occasionally it has a faint greenish tinge. Hardness = 4·5, specific gravity 2·73. An analysis yielded the following results:

B_2O_3 27·74 SiO_2 28·45 CaO 34·88 H_2O 8·30 Al_2O_3, Fe_2O_3 0·63 = 100.

From this the formula is calculated $6SiO_2 . 5B_2O_3 . 8CaO . 6H_2O$. The mineral is named after Mr. R. C. Baker, a director of the company. It is noted that howlite also occurs in large quantities in the same mines.—*Min. Mag.*, xiii, 353.

Erikite is a new species from the nephelite-syenite of Julianehaab, Greenland, described by O. B. Böggild. It occurs in orthorhombic crystals, sometimes highly modified, of a yellowish

brown to dark grayish brown color. Specific gravity 3·493, hardness 5·5 to 6. The crystals are opaque and under the microscope are seen to have a pseudomorph-like structure consisting of a complex yellow substance of strong double refraction and a colorless one feebly birefringent. An analysis by Chr. Christensen yielded :

SiO_2	P_2O_5	$(Ce, La, Di)_2O_3$	ThO_2	Al_2O_3	CaO	Na_2O	H_2O
15·12	17·78	40·51	3·26	9·28	1·81	5·63	6·28 = 99·67

The formula of the mineral is doubtful because of the alteration it has undergone. Erikite is named after Erik the Red, who discovered Greenland in 986. The same author gives a further description of the rare species *schizolite* (see this Journal, x, 325, 1900), first described by Winther from the same region in Greenland. It is shown to be triclinic in crystallization and nearly similar in form to pectolite and wollastonite; it is also related to rhodonite and babingtonite.—*Medd. om Grönland,* xxvi, 1903.

Cryolithionite is a new fluoride of aluminium, sodium and lithium described by N.-V. Ussing from the cryolite locality at Ivigtut, Greenland. It occurs in large dodecahedral crystals which are colorless and show distinct dodecahedral cleavage. The hardness is 2·5 to 3 and the specific gravity 2·777. An analysis of purified material gave :

F 60·79 Al 14·46 Na 18·83 Li 5·35 ign 0·36 = 99·79

This leads to the formula $Li_3Na_3Al_2F_{12}$, which corresponds to a cryolite with half the sodium replaced by lithium.—*Bull. Acad. Sci. Lettr. Danemark,* No. 1, 1904.

Thorianite is a new radio-active species from the gem washings at Balangoda, Ceylon, named by W. Dunstan ; it has also been observed in pegmatite at Gampola, Ceylon. It occurs in black cubical crystals of specific gravity 9·32. An analysis by G. S. Blake gave the following results :

ThO_2	$(Ce, La, Di)_2O_3$	UO_3	ZrO_2	Fe_2O_3	PbO	SiO_2
76·22	8·04	12·33	*tr*	0·35	2·87	0·12 = 99·93

The same mineral has been examined by W. Ramsay as to its radio-activity and chemical composition, with results in the latter direction that do not agree with the analysis above quoted.—*Nature,* lxix, 510, 533, 559.

5. *New York State Museum.* 22d Report of State Geologist, 1902. 186 pp., 29 pls.—In addition to the economic work conducted under Dr. Merrill's direction, investigations on the crystalline and Pleistocene rocks were continued.

New occurrences of anorthosite on the Langlake sheet are reported and studied by Prof. Cushing. Prof. Woodworth continued his detailed study of the Hudson-Champlain depression and mapped new shore lines marked by bars, embankments and terraces. Pages 17–41 of the present report is a paper by Prof. H. L. Fairchild on Glacial Waters from Oneida to Little Falls. The history of the Mohawk Valley drainage is divided into three stages: 1. Pre-Iroquois waters—lacustine, and fluviatile, held in

the valley during the ice retreat ; 2. Iromohawk river—draining glacial lake Iroquois and cutting the rock channel at little falls; 3. The Mohawk River.

6. *Observations of a Naturalist in the Pacific;* by H. B. Guppy. Vol. I, Vanua Levu, Fiji, xix, 392 pp., 7 plates, 2 maps, 20 figures. London, 1903 (Macmillan & Co.).—This handsome volume describes in great detail the geology and petrography of Vanua Levu. The author concludes that "Vanua Levu is a composite island built up during a long period of emergence, that began probably in the late Tertiary period, by the union of a number of islands of volcanic formation." The platform on which the island rests is supposed to be built up of submarine basaltic flows. The rocks are chiefly basalts and andesites, with a few dacites, trachytes, quartz-porphyries, gabbros and diorites. The author adopts a peculiar classification of his own for these: Classes being based on the ferromagnesian mineral present, the Sub-classes on the presence or absence of groundmass, Orders on the arrangement of the groundmass feldspars, Sub-orders on the ferromagnesian mineral of the groundmass, Sections on the presence or absence of feldspar phenocrysts, Genera on the vitreous or opaque character of these, and Species on their length. There is no discussion of the reasons for the adoption of this classification, criticism of which is uncalled for here. Although the rocks are described petrographically in great detail, not a single chemical analysis of them is given. A chapter is devoted to the magnetic characters of the volcanic rocks, many of which are stated to show marked polarity. Vol. II will deal with the dispersal and distribution of Pacific plants. H. S. WASHINGTON.

II. Miscellaneous Scientific Intelligence.

1. *Elements of Algebra for Beginners;* by George W. Hull, 159 pp. American Book Company.—This little book has been prepared for young pupils as a substitute for some of the later work in arithmetic. It does not afford a basis of instruction adequate for preparation for college examinations, nor does it aim to do so. For teaching the technique of algebra, the book is admirably adapted, though in some cases, notably in evasion of negative numbers, the aim for simplicity runs counter to sound science. The collection of examples includes many simple ones carefully graded. H. E. H.

2. *Elementary Algebra;* by J. H. Tanner. American Book Company.—This book is adequate for the preparation of students for the examinations in Elementary Algebra for any college or scientific school. The development of the numbers used in algebra is careful, and the most striking feature of the book. To a class of somewhat mature students, the book would undoubtedly be of value. H. E. H.

A "Complete Mineral Catalog" in handsomely printed form has recently been issued by the Foote Mineral Co. 216 pp., price 25c., in flexible cloth, 50c.

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Established by BENJAMIN SILLIMAN in 1818.

THE

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FOURTH SERIES.

VOL. XVIII—[WHOLE NUMBER, CLXVIII.]

No. 106.—OCTOBER, 1904.

WITH PLATES XI–XVI.

NEW HAVEN, CONNECTICUT.
1904

THE TUTTLE, MOREHOUSE & TAYLOR CO., PRINTERS, 123 TEMPLE STREET.

Published monthly. Six dollars per year, in advance. $6.40 to countries in the Postal Union. Remittances should be made either by money orders, registered letters, or bank checks (preferably on New York banks).

THE

AMERICAN JOURNAL OF SCIENCE

[FOURTH SERIES.]

ART. XXVIII.—*A New Devonian Formation in Colorado;* by WHITMAN CROSS.

THE existence of Devonian formations in the San Juan region of Colorado was first established through the discovery of invertebrate fossils by F. M. Endlich of the Hayden Survey, during the summer of 1874.* The Devonian character of the fauna discovered by Endlich was announced by F. B. Meek,† later questioned by C. A. White‡ and R. P. Whitfield,§ reaffirmed by C. Schuchert,** and finally established by G. H. Girty†† upon the basis of extensive collections from many localities obtained during the survey of the San Juan country under the direction of the writer. The limestone formation, from which Endlich collected a few fossils and which has yielded the extensive fauna studied by Girty, was described by A. C. Spencer,‡‡ at the time the writer's assistant in the Colorado work, as the *Ouray Limestone*. It has been found, since the cited publications by Spencer and Girty, that the upper part of the lithologic unit, the Ouray limestone, contains a Mississippian Carboniferous fauna. This has now been described by Girty,§§ in his review of the known Carboniferous

* Ann. Rep. U. S. Geol. and Geog. Survey, etc., for 1874, pp. 211-214.
† Bull. U. S. Geol. and Geog. Survey, etc., 2d Ser., No. 1, 1875, p. 46.
‡ Bull. U. S. Geol. and Geog. Survey, Terr., 2d Ser., No. 1., 1875, p. 47.
§ U. S. Geol. Survey, Monog. XII, 1886, p. 56.
** Bull. U. S. Geol. Survey, No. 87, p. 166.
†† Devonian fossils from Colorado. The Fauna of the Ouray Limestone. U. S. Geol. Survey, 20th Ann. Rep., Pt. II, 1900, pp. 25-81.
‡‡ "Devonian Strata in Colorado," this Journal (4), ix, 1900, p. 125.
§§ "The Carboniferous Formations and Faunas of Colorado;" Profession. Paper No. 16, U. S. Geol. Survey, 1903.

invertebrates of Colorado. The Ouray limestone has been studied in several quadrangles of the San Juan region, the original locality at which its Devonian fauna was first discovered by Endlich has been revisited, and its position as a well determined unit in the Paleozoic section of Colorado must be considered as established. The present paper refers to the immediately underlying formation, in which Endlich found fish remains, and which is now for the first time given a distinctive name.

The locality at which Endlich first observed the Devonian strata lies upon the southern slope of the Needle Mountains, about 10 miles east of the Animas canyon at Rockwood, and on the western rim of the Vallecito canyon. The beds are very near the base of the Paleozoic section which dips southerly under the influence of the post-Laramie domal uplift about the Needle Mountains center. Erosion has removed the sediments over a large area, in places exposing the coarse-grained granite upon which they rest and here and there leaving tongues or isolated patches of the lower formations.

The Devonian invertebrates were found by Endlich at a triangulation station, obscurely referred to in his report as "Station 48," which is easily identifiable from the topographic report of 1874 as the point of elevation 12,305 feet, according to the Hayden map, directly overlooking the Vallecito canyon and a little south of the boundary of the Needle Mountains quadrangle. A stone monument still stands at the point, upon a remnant of Ouray limestone very rich in fossils and near the base of the formation. A branch of the Vallecito, heading west of the point, cuts it off from the main sloping mesa of sedimentary rocks, which begins a half mile to the southwest. In the absence of sufficient geographic terms for descriptive purposes, the writer proposes the name "Devon Point" for this knoll capped by Ouray limestone, the "Station 48" of the Hayden survey, which must become a classic spot in the discussion of the Colorado Devonian. The name Endlich Mesa has already been given, upon the Needle Mountains topographic map, to the gently dipping surface of granite and thin overlying Paleozoic beds which lie between the Vallecito and the Florida rivers, and is terminated by the headwaters of the latter stream. Devon Point lies on the eastern edge of Endlich Mesa.

Below the triangulation monument of Devon Point there are but about 25 feet of the Ouray limestone. Intervening between the limestone and the granite are two distinct formations referred to by Endlich* in the following terms, which (as to the upper

* Loc. cit. pp. 211, 212.

one) specifically apply to the exposures southwest of Devon Point about one-half mile, where the sediments reappear beyond the stream above mentioned, which has cut through them into the granite. They apply as well, however, to the strata at Devon Point.

"Resting immediately upon this granite, which showed a very marked stratification, conformable with that of the superincumbent sedimentary beds, a white to red and brown quartzite was found. At some points the contact of the latter with the granite was so intimate that specimens could be obtained, showing both the granular quartzite and the coarse-grained granite on the same piece. No definite relation of the colors exhibited by the quartzite could be established, save the general rule that the nearer it was to the underlying metamorphic rock, the more intensely it was colored." * * "Above the quartzite is a thin stratum of yellow siliceous shales, containing narrow interstrata of softer shales. In these the well-known and characteristic pseudomorphs after salt were found. During the formation of the Devonian beach that now remains quartzite and quartzitic shales, portions of the water, that even at so early a geological period contained sodium chloride, were separated from the main body. Upon evaporation the mineral constituents of the water crystallized. Subsequent inundations of the places that had scarcely been laid dry, brought with them sand and silt, covering the newly formed crystals. By the gradual percolation of water through the cover the salt was dissolved, and a quantity of the material composing the cover found its way into the cavities thus produced. It will be noticed, therefore, that whenever these pseudomorphs of sand after salt are found *in positu*, the crystals will be observed on the *lower* side of the stratum containing them. Occurrences of this kind are not infrequent in younger formations both of this country and Europe. Besides these pseudomorphs, scales and fragments of bones are found, belonging to some fish of considerable size. Too little material could be collected to admit of any identification, even only generically. Small scutellae also occur, probably belonging to the same animal. This stratum, as well as the quartzite underlying it, can be traced on the southern side of the granite strip." *

In the summer of 1901 the southern portion of the Needle

* Endlich conceived the granite of this region to be an extreme product of the metamorphism of early Paleozoic sediments, and this view seems to have influenced his statement that at Devon Point the granite "showed a very marked stratification, conformable with that of the superincumbent sedimentary beds." In fact, the granite is unusually coarse-grained, massive, and homogeneous in composition, exhibiting nothing to warrant the repeated references to its origin from sediments.

Mountains quadrangle was mapped geologically by the writer, assisted by Ernest Howe and J. Morgan Clements. Devon Point and the exposures to the southwest were visited, but as the remark of Endlich concerning the fish remains had escaped attention, they were overlooked in the effort to secure fossils from the Ouray limestone. In 1903, however, a special trip was made by the writer and Mr. Albert Johannsen to Devon Point and the adjacent exposures in special search for the fish remains.

The relation of the beds at this locality is shown in the accompanying detailed section.

Section of Paleozoic Formations, Devon Point, Colorado.

TOP.		FEET.
	Ouray limestone remnant, estimated	25
	Elbert formation.	
12.	Red shale or clay. Strong red color, uniform composition; when dry makes soft, crumbling flakes at exposures	5
11.	Sandstone or quartzite. A layer of variable grain, fine or coarse, not persistent, gray, full of fragments of fish scales in some places; free from them in others	± 1
10.	Calcareous shales and thin limestone, buff or gray in color, breaking up readily into slabs or flakes. Salt casts are common in this division. A thin, discontinuous red purplish, sandy layer full of scale fragments occurs locally	25
9.	Thin layers of quartzite, limestone, and red calcareous shale, alternating. Limestone is arenaceous, dull gray, few layers reaching 6 inches in thickness	8
8.	Quartzite, fine-grained, gray, hard, in layers 2 or 3 inches thick	2–$\frac{1}{2}$
7.	Red, calcareous shale	1–$\frac{1}{3}$
6.	Limestone, yellow, earthy	–$\frac{3}{4}$
5.	Calcareous and sandy shales, variegated, yellow, buff, lilac	1–$\frac{1}{3}$
4.	Quartzite, fine-grained, yellow-brown	1–
3.	Sandy shale, a harder layer in middle. Red, greenish, or mottled	5–
2.	Sandy limestone, shaly in part, rich in fish scales and plates	± 1–
1.	Red shale, calcareous, and sandy, with specks of bone or shell	2–
		54

TOP.	FEET.
Ignacio formation.	
5. Quartzite conglomerate with small pebbles, gray or pink, hard and causing a distinct ledge (may belong to Elbert)	3–½
4. Quartzose sandstone and sandy shale, dark dull red, in layers 6 inches or less in thickness	5
3. Quartzite, fine-grained, hard, gray, in beds 1 to 5 feet in thickness with thin shale partings. Cross-bedding common	24
2. Sandstone and quartzite, fine and uneven grain in beds 2 or 3 feet thick, with red, sandy shale layers between	17
1. Crumbling shaly sandstone, dark, dull red in color, mainly of quartz with some red feldspar grains. A coating of limonite on particles causes color	2–½
	52–

Base of section is coarse biotite-granite.

The quartzite formation, measuring 52 feet in thickness at Devon Point, is called the Ignacio quartzite in the Silverton folio (now in press) and it is believed to be of Upper Cambrian age, since the only fossil thus far found in it is a small shell which, according to Mr. Charles D. Walcott, is apparently an *Obolus*, closely related to *O. loperi*, known elsewhere in Colorado. The strata between the quartzites and the Ouray limestone, carrying fish remains at the base and also near the top, seem unquestionably to form a lithologic stratigraphic and faunal unit, and for these strata the name *Elbert formation* is here proposed. The name is derived from Elbert creek, a western tributary of the Animas, entering it just above Rockwood, which flows for several miles on a broad bench between the Animas canyon and the high scarp formed by the Hermosa Upper Carboniferous formation. On this bench the Ignacio, Elbert and Ouray formations are particularly well exhibited. The first name is from the Ignacio lakes, lying on this bench and drained by Elbert creek.

The Elbert formation has been observed below the Ouray limestone in several quadrangles of the San Juan region and many exposures have been studied. While the reader is referred for details to the Needle Mountains, Durango, Engineer Mountain, and Silverton folios, now in press, or soon to be completed, some statements of its characteristics may be made.

Its general lithologic character is fairly well illustrated by the section at Devon Point, although many of them have been noted. The most persistent feature is the crumbling calcareous

shale division, with its casts of salt crystals, by which it may quickly be recognized in nearly all localities. Especially where the formation is found capping a bench or isolated knoll, as at Overlook Point and several other places on the granite surface north from Endlich Mesa, the thin limestone slabs covered with these casts are often very abundant. As was noted by Endlich, the casts were found on the under-surface of layers and testify to peculiar local conditions. While commonly on earthy limestone, the casts have been noted on coarse quartzose sandstone. The most important variation in the lithologic character of the Elbert formation is in the appearance of dense, earthy limestone of conchoidal fracture, in several beds in its upper portion. This development is most notable on the west flank of the Needle Mountains, and also at Bluebird Park, in the northwestern section of the Needle Mountains quadrangle.

The only fossils as yet obtained from the Elbert formation are fish remains, and the most productive locality discovered is that of Devon Point, already described. The remains were found at the base, and also very near the top of the section referred to the Elbert, showing the formation to be a well defined unit as to its fauna. Fish remains have also been discovered at two other localities, to be briefly mentioned.

At about one mile south of Rockwood, and close to the railroad track, a block of pale reddish quartzite was found at the base of the talus slope, upon which were rather indistinct remains of three individual fishes. The ledge of quartzite just above this talus heap belongs to the Ignacio Cambrian quartzite, but the sloping bench between that ledge and the cliff of Ouray limestone some yards farther back is occupied by the Elbert formation. Repeated search has failed to reveal the stratum from which the fish-bearing slab came, and no other remains were obtained. It is almost certain, however, that the slab in question came from a thin bed in the lower part of the Elbert section.

Another, and somewhat different, occurrence of fish remains was found on Little Cascade creek, about one-half mile south of Columbine lake and seven and one-half miles north of Rockwood. At this point the shales containing salt casts are succeeded by several massive limestones alternating with shaly strata. Several thin layers rich in finely comminuted fish scales or plates occur beneath the limestones, and in one of the limestones, resting with irregular contact upon such a layer, a few large plates were found.

All the fish remains above mentioned have been examined by Dr. C. R. Eastman, who, in the accompanying paper, describes the fauna represented by them and discusses their interest from the paleontological standpoint. From the strati-

graphic point of view, the discovery of this distinct ichthyic fauna leads to certain correlations and gives much desired information concerning the lower Paleozoic section of western Colorado.

The most evident correlation of the Elbert formation is with the so-called "Parting Quartzite" of central Colorado, in which Spurr found fish remains determined by Eastman as of Upper Devonian character, and related to certain forms from the Elbert formation.

The name "Parting Quartzite" was used by Emmons in the Leadville monograph* for a quartzite formation 70 feet or less in thickness, occurring below the "Blue Limestone" in which Lower Carboniferous fossils had been found, and the "White Limestone," supposed to be of Silurian age. The "Parting Quartzite" was also provisionally assigned to the Silurian.

At Aspen, on the northeastern flank of the Elk mountains, Spurr † found the beds corresponding in stratigraphic position to the Parting Quartzite of Leadville, to consist of alternating dolomite, dolomitic shale, and quartzite, the last on the whole subordinate, but the old name for the formation was retained. From certain shaly beds at Aspen, Spurr and Tower obtained the fish remains referred to by Dr. Eastman in the accompanying paper. Upon the provisional determinations of this material by Walcott and Girty, the Devonian age of the "Parting Quartzite" was advocated by Spurr. He also pointed out the resemblance of the fish-bearing formation of Aspen to the beds observed by Walcott ‡ in the lower Kanab valley of Arizona, briefly stated to contain "placoganoid fishes of a Devonian type."

The stratigraphic equivalence of the Elbert formation of the San Juan region with the "Parting Quartzite" is further supported by the correlation of the Ouray and Leadville (Blue) limestones, rendered necessary by the studies of Girty, who shows that both possess an upper Devonian invertebrate fauna in their lower portions and a Mississippian fauna in their uppermost strata. The Carboniferous forms only were found at Leadville, and the Devonian fauna was the first obtained from the Ouray limestone.

The correlation of the Elbert formation and the "Parting Quartzite" with the strata of the Kanab valley, already suggested by Spurr, is of special interest in view of the relations of the Elbert fishes and the suggestions made by Eastman regarding the geographic connections of that fauna. Unfortu-

* Mon. U. S. Geol. Survey, vol. XII, p. 61.

† "Geology of the Aspen Mining District, Colorado," U. S. Geol. Survey, Mon. XXXI, 1898, pp. 13-22.

‡ This Journal (3), vol. xx, 1880, p. 224.

nately the fossils obtained by Walcott in the Kanab section are not at present available for comparison with the Colorado forms. As Spencer pointed out in discussing the relations of the Ouray limestone,* "it is very probable that the lower part of the Red Wall limestone [Kanab section] is equivalent in age, as well as in position, to the Devonian limestone of Colorado."

While certain correlations for both the Elbert and Ouray formations seem definitely indicated by present knowledge, meagre as it is in some directions, there is a marked contrast between the lower Paleozoic section of western Colorado and that of the Front range, especially as exhibited near Canyon City.

A marked difference also exists between the Kanab section and that of central Nevada, and other localities of the Great Basin. The faunal problem involved is pointed out by Dr. Eastman, and it is clear that the conditions controlling the character of the sedimentary beds form also a most inviting subject for investigation.

* This Journal (4), vol. ix, 1900, p. 133.

Art. XXIX.—*On Upper Devonian Fish Remains from Colorado;** by C. R. Eastman.

Through the courtesy of Drs. Whitman Cross and T. W. Stanton, of the United States Geological Survey, a number of Paleozoic fish remains from Colorado have recently been placed in the hands of the writer for investigation. The greater number of these were collected by Dr. Cross in the San Juan region, while engaged on the survey of the Durango, Engineer Mountain, and Needle Mountains quadrangles. A few detached plates and scales from Aspen, collected some years ago by J. E. Spurr, complete the collection. The character of the remains is indicative of an Upper Devonian horizon for all the localities, and in the case of at least two of them, an Upper Devonian invertebrate fauna has been found in beds overlying the fish-bearing strata. For an interesting account of the stratigraphy of the region, the reader is referred to the preceding paper by Dr. Cross, wherein the name of Elbert formation is proposed for the fish-bearing beds. In the present article it will be sufficient to point out the general nature of the vertebrate fauna, and to inquire into its relations with other Devonian assemblages. The several localities may be considered in the following order.

Durango Quadrangle.

The specimens from the Elbert formation of Rockwood being of exceptional interest, the details of their occurrence may be noted rather fully. They are all from a single slab of quartzite found in the talus at the base of a cliff about one mile south of Rockwood. It is stated by Dr. Cross in memoranda accompanying these specimens that their probable source, as indicated by lithological evidence, is "at least 100 feet above the basal conglomerate, which here rests upon granite. Above the quartzite ledge, with a small covered interval, comes the Ouray limestone, containing a Devonian invertebrate fauna. The variable quartzite series below the limestone in the Animas Valley never exceed 300 feet in thickness, and have yielded no other forms, though carefully searched for a number of miles along the outcrop. . . . The occurrence of fish remains in the Silurian at Canyon City, as described by Walcott, suggests that these fish remains from near Rockwood belong to Silurian beds intermediate between the Cambrian and the Devonian. Very careful search did not suffice to detect the layer from which the slab in question came." In a

* Published by permission of the Director of the United States Geological Survey.

later communication he remarks that "the greater part of the quartzite above the talus heap is supposed to belong to the Cambrian member of the series, and the Elbert formation is known on the little bench just at the head of the talus pile. For some time past I have regarded it as almost certain that the slab came from the Elbert formation."

The recognizable specimens on this slab are three in number, and all belong to a large species of Bothriolepis which cannot be identified with any previously described. Exceed-

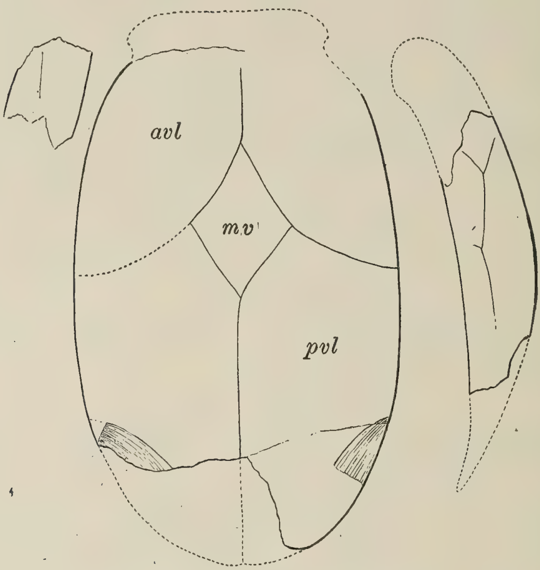

FIG. 1.—*Bothriolepis coloradensis*, sp. nov. × ½.

ing the average of *B. canadensis* in size, it is slightly inferior to *B. major;* but from both of these the new species is distinguished by its different style of superficial ornamentation, general proportions of the body and appendages, and by peculiarities in the outline and structure of the ventral plates. It is difficult to frame a satisfactory diagnosis of the new form, all three individuals presenting only the ventral aspect, and none of them exhibiting the head, though the pectoral members are attached. At the same time it is possible to form a fairly accurate concept of the relations between this and other species, and for sake of comparison with the well known *B. major*, figures are given showing the topography of the ventral surface in each (figs. 1, 2). In *B. canadensis* the rhom-

boidal median ventral is relatively smaller, and the surface ornamentation of all the plates is finer and of different pattern. The appendages, too, are longer, and more tapering distally. *B. major* has the median ventral larger and more exposed than in any known species, its outline being sometimes polygonal or slightly rounded (fig. 3). The remaining species of Both-

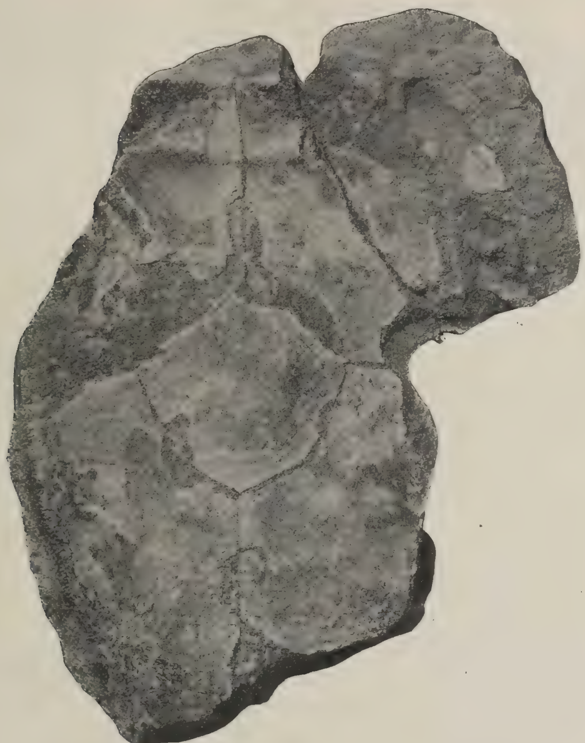

FIG. 2.—*Bothriolepis major* (Ag.). $\times \frac{5}{9}$.

riolepis are excluded from comparison with the new form, which may be known as *B. coloradensis*, by reason of their smaller size, or nature of their superficial ornamentation.

The ornament of *B. coloradensis*, though by no means so well preserved as one might wish in the Rockwood specimens, is clearly of the tuberculate order; here and there the tubercles appear to be more or less confluent, but nowhere do they fuse into vermiculating ridges, as in other American and some foreign species. The center of ossification in the posterior

ventrals is situated near the outer margin some distance behind the middle of the plate; in advance of this point the vascular canals radiate in all directions between parallel with and at right angles to the median line, but behind it they are crowded together and directed obliquely backward. This condition is apparent in all three individuals, and is indicated by the shading in fig. 1.

The ventral armour of the best preserved individual, that shown in the figure, has a width across the middle portion of 8·5^{cm}, and an estimated total length of about 14^{cm}. The largest

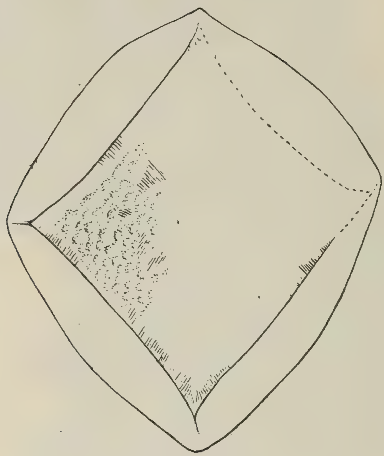

FIG. 3.—*Bothriolepis major* (Ag.). Median ventral, × $\frac{1}{1}$.

example of *B. canadensis* with which the writer is acquainted displays a corresponding width of 10^{cm}, and length of 16^{cm}. *B. major* attains even larger dimensions, the carapace and head, according to Traquair, measuring sometimes 1·5 feet. The length of the pectoral appendages in the new form appear to be intermediate between those of the above-named species, but their covering plates are not sufficiently well preserved to permit of detailed comparisons. In the drawing, the distal end of one of the appendages, which is not serrated, and also a portion of the left posterior ventral have been added from a second specimen, otherwise the parts are shown as they occur in a single individual. The outline of the median and posterior ventrals is perfectly distinct, but the remaining sutures, including those of the pectoral members, are unfortunately obliterated. A very unusual feature in this genus is the obtusely rounded posterior margin of the plastron. On the whole, it appears probable that the relations of the Colorado

species are closer to the European *B. major* than to any other member of the genus.

Needle Mountains Quadrangle.

The principal fossiliferous localities of the Elbert formation, and at the same time historically the most interesting, are those occurring along the eastern edge of the Endlich mesa, *Devon Point* being the name given by Dr. Cross to the most productive. Here the fish remains are distributed throughout beds near the base, and also near the top of the section, being in fact so abundant as almost to justify the name of "fish-bed." And yet the variety of forms represented is surprisingly meagre. Portions of Bothriolepis armour are plentiful, probably not more than two species being represented, however. In addition there occur scales belonging to two species of Holoptychius, but this is all. No Dipnoan remains, and no Arthrodires, which invariably accompany Bothriolepis and Holoptychius in the Upper Devonian, are at present known from this locality. In fig. 4 is shown a weathered fragment of a pectoral limb of Bothriolepis, the external layer having been removed, and the bone substance appearing in longitudinal section. No characters remain for determining the species, yet its large size appears to indicate an identity with *B. coloradensis*. Some of the smaller fragments display an ornament of vermiculating ridges similar in all respects to that observed in *B. leidyi*, from the Catskill of Pennsylvania; and in the absence of more decisive evidence, they may be provisionally referred to that species.

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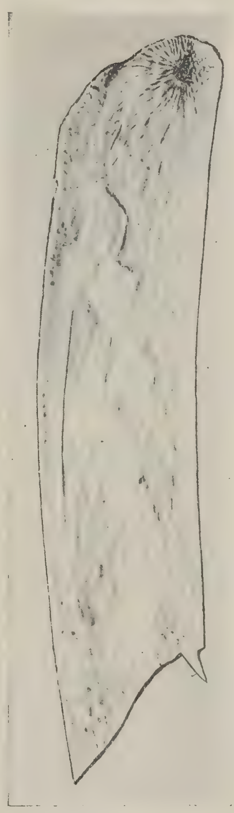

The scales of Holoptychius shown in figs. 5 and 6 are preserved in the form of impressions, but the characteristic tubercles and ridges of the exposed surface are clearly indicated. Both of these scales fall within the limits of *H. giganteus*, according to the original definition of that species as given by

Agassiz, allowance having been made by him for variation amongst scales belonging to different parts of the body in the same fish. The species was subsequently divided by Newberry, who included under the name of *H. tuberculatus* those scales in which the tubercles remained distinct, and were not fused into continuous, longitudinal ridges. As for Newberry's *H. americanus*, this resembles Agassiz's species in having the ridges irregularly tortuous, and more or less interrupted and branching, hence it will be seen that the precise determination

FIG. 5.—*Holoptychius giganteus* Ag. Scale, × $\frac{1}{1}$.

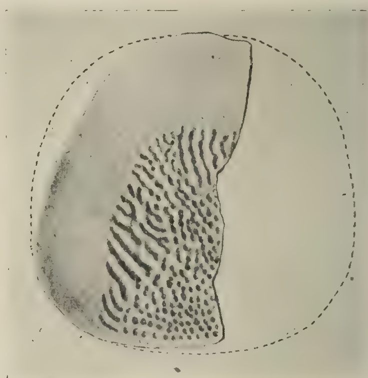

FIG. 6.—*Holoptychius tuberculatus* Newb. Scale, × $\frac{1}{1}$.

of detached scales is a matter of some difficulty. Probably we shall not err greatly in identifying the original of fig. 5 as *H. giganteus* Ag., and that of fig. 6 as *H. tuberculatus* Newb.

Engineer Mountain Quadrangle.

From Station No. 209, a locality on Little Cascade Creek, one half mile south of Columbine Lake, Engineer Mountain Quadrangle, a single finely tuberculated plate was obtained by Dr. Cross, which appears to be a posterior ventral of some Arthrodire, of about twice the size of the type species of Coccosteus. Occurring as it does in the detached condition, and more or less injured by weathering, even an approximate determination is impossible.

Pitkin County.

The few fragments obtained by Mr. Spurr from the vicinity of Aspen are poorly preserved, and specifically indeterminable.* Two or three finally tuberculated plates are probably to be regarded as of Arthrodire nature, and the presence of

* This remark applies only to the small portion of Mr. Spurr's collection which has as yet come under the writer's observation. At the time this article was written, it was not practicable to obtain access to the remaining

Dipnoans is indicated by certain smooth scales displaying their characteristic perforations. These latter, however, are noteworthy for furnishing the only indication we possess at present of the occurrence of Lung-fishes in the Colorado Devonian.

General Conclusions.

It has already been remarked that the remains brought to light by Dr. Cross are indicative of an Upper Devonian horizon. No other conclusion seems possible in view of the fact that Bothriolepis is an exclusively Upper Devonian genus, and the greater number of Holoptychius species occur in beds of the same age. The two species of the former genus already known from this country, and dozen or so of Holoptychius, are limited to the Chemung and Catskill groups of New York and Pennsylvania. One species of Bothriolepis (*B. canadensis* Whiteaves), and one of Holoptychius, have been described from the Upper Devonian of the Province of Quebec, Canada. These genera are represented abroad by various species found in the Upper Old Red Sandstone of Scotland, and in the Upper Devonian of Belgium and Northwest Russia. The vertebrate fauna of which they form part is composed of Ostracophores, Arthrodires, Dipnoans, Crossopterygians and Elasmobranchs, and it is interesting to note that all of these groups with the exception of the last-named are represented in the Colorado Devonian.

Regarding the origin of the Colorado fauna, little can be said with positiveness. The new species of Bothriolepis appears to be most closely related to *B. major* of Scotland and Russia, and if the fragments showing vermiculated ornamentation are correctly interpreted as belonging to *B. leidyi*, this identification, with that of *Holoptychius giganteus*, place the fauna in relation with the Catskill of Pennsylvania. The Chemung-Catskill of the eastern States betrays an unmistakably European origin, but there is good reason to suppose that a barrier existed between the eastern and western regions during the late Devonian, since neither Holoptychius nor Bothriolepis remains have been found west of New York and Pennsylvania. From this latter region also, the Upper Devonian Ptyctodonts and Dipnoans of Iowa and contiguous States were entirely excluded. Assuming that there was no connection between the eastern and western areas toward the close of the Devo-

specimens, nor to the interesting material collected by Dr. C. D. Walcott from the lower Kanab canyon of Arizona in 1879, owing to the limited storage facilities of the Museum, and absence from Washington of the proper custodians. Mr. Walcott's only publication in regard to the Kanab material is to be found in this Journal [3], vol. xx, p. 224.

The Aspen material is briefly described by Dr. G. H. Girty, in vol. xxxi, p. 20, of U. S. G. S. Monographs (J. E. Spurr: *Geology of the Aspen Mining District*). Without having actually seen the teeth, which are there provisionally referred to "Rhizodus," a Carboniferous genus, we may be permitted to hazard the presumption of their belonging to Holoptychius.

nian, it is difficult to understand how members of the Chemung-Catskill fauna could have reached Colorado, unless they came by some southern route as yet unknown. On the other hand, a Eurasiatic origin by way of Behring Straits cannot be regarded as an impossibility, nor even as an improbability, since the invertebrate fauna of the superjacent formation has been shown by Dr. Girty* to be "not closely similar to the faunas of the eastern and central United States," but exhibits, in his opinion, "a closer parallel with the Devonian of the Ural Mountains."

Attention should also be called to Professor Calvin's observations on the Devonian system of Iowa, which go to show that the eastern and western areas were geologically isolated. According to this author,† "the eastern Devonian faunas probably migrated from the northeast along the eastern border of the continental nucleus, while the western faunas of the same period seem to have come from the northwest along the western border of the Devonian continent." He also points out that the Iowa Devonian fauna is related in some respects to that occurring at the Ramparts of the Mackenzie River, and the present writer has commented on certain resemblances between its vertebrate constituents and the corresponding fauna of Russia.

For the present, the question as to the origin of the vertebrate fauna of the Colorado Devonian must be considered as problematical, and one which will require considerable further evidence and investigation before it can be answered satisfactorily. It is evident that the remains thus far obtained by Dr. Cross constitute not only an important paleontological discovery, but open up problems of distribution, and others of a geological nature, which are worthy of careful study.

Harvard University, Cambridge, Mass.

EXPLANATIONS OF FIGURES.

FIGURE 1.—*Bothriolepis coloradensis* sp. nov. Elbert formation; Rockwood, Col. Ventral armour, ½ natural size. *avl*, Antero-ventro-lateral; *mo*, Median ventral; *pvl*, Postero-ventro-lateral plates. (U. S. Nat. Mus.)

FIGURE 2.—*Bothriolepis major* (Ag.). Upper Old Red Sandstone; Elgin, Scotland. Ventral armour, seen from the visceral aspect, × 5/9. (Original in Mus. Comp. Zoöl. at Cambridge.)

FIGURE 3.—*Bothriolepis major* (Ag.). Median ventral, × 1/1. *Ibid.*

FIGURE 4.—*Bothriolepis coloradensis* (?) sp. nov. Fragmentary pectoral appendage, × 1/1. Elbert formation; Devon Point, Colorado.

FIGURE 5.—*Holoptychius giganteus* Ag. × 1/1. Same locality.

FIGURE 6.—*Holoptychius tuberculatus* Newb. × 1/1. Same locality.

* The Carboniferous Formations and Faunas of Colorado (Profess. Paper U. S. Geol. Surv., No. 16, p. 162), 1903.

† Ann. Rept. Iowa Geol. Surv., vol. VIII (1897), p. 221. One may compare also the following important papers on Devonian paleontology: Schuchert, C., On the Faunal Provinces of the Middle Devonic of America, etc. (Amer. Geol., vol. xxxii, pp. 137–162), 1903. Williams, H. S., The Correlation of Geological Faunas (Bull. U. S. Geol. Surv., No. 210), 1903.

Art. XXX.—*On some Fossil Turtles belonging to the Marsh Collection in Yale University Museum;* by O. P. Hay. (With Plates XI–XVI.)

The present paper is the result of a study of some of the extinct turtles in the collections of vertebrate fossils brought together by Professor O. C. Marsh. The privilege of making the investigation was first granted by the late Professor Charles E. Beecher; after his death it was renewed by the acting curator of the collection, Professor L. V. Pirsson. For assistance and courtesy the writer's thanks are due to all the officers having connection with the department of vertebrate paleontology in Yale University. The negatives from which several of the plates have been prepared were furnished by Dr. George R. Wieland. The wash drawings were made by Mr. Erwin Christman, of the American Museum of Natural History.

Further remarks on the species here treated and additional illustrations will, it is hoped, be presented in the writer's forthcoming monograph of the fossil turtles of North America.

Baëna marshi sp. nov.

Plate XI; Text-figure 1.

The type of this species was collected in 1889, by Professor J. B. Hatcher, in the Laramie deposits of Converse County, Wyoming, between Buck and Lance creeks.

The specimen has suffered considerable damage. There are present the central region of the carapace and most of the left side, the greater portion of the plastron, and the matrix forming a cast of the interior of the shell. The length of the shell can be determined only approximately. It must have been at least 300^{mm}, with a breadth of 220^{mm}.

On account of the obliteration of the sutures of the carapace, its structure cannot be made out. The bones along the median region have a thickness of from 10 to 13^{mm}. The outer surface is smooth. The sulci between the various dermal scutes are narrow and shallow, and in many places cannot be traced. The second, third, and fourth vertebral scutes varied in width from 64 to 70^{mm}.

The posterior extremity of the plastron is missing; hence the length of the plastron cannot be accurately determined, nor the form of the posterior margin. The total length, however, must have been close to 260^{mm}. The following table presents the most important dimensions. In order that the distinctness of the species from *B. hatcheri*, which is from the same deposits and locality, may be appreciated, the dimensions of the plastron of the latter are also given.

Dimensions.	*Baëna marshi.*	*Baëna hatcheri.*
Length of plastron	260±	305
Width of bridge	120	115
Length of anterior lobe	70	106
Width of anterior lobe	95	115
Length of posterior lobe	65±	98
Width of posterior lobe	90	120

1

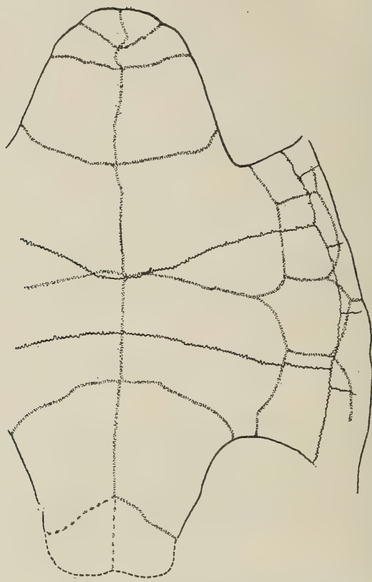

FIGURE 1.—*Baëna marshi.* Diagram of plastron.

It will be observed that, while the plastron of *B. hatcheri* is considerably longer, the bridge is slightly shorter. Further, the lengths of the anterior and posterior lobes of *B. marshi* are much less in proportion to the total length of the plastron than they are in *B. hatcheri.*

The central region of the plastron is concave. This may indicate that the individual was a male. The mesoplastra are large, wedge-shaped bones. They meet along the midline for a distance of 23^{mm}, and their outer ends are 65^{mm} wide.

The following are the antero-posterior widths of the various plastral scutes: Intergulars, 17^{mm}; gulars, 10^{mm}; humerals, 46^{mm}; pectorals, 50^{mm}; abdominals, 47^{mm}; femorals, 53^{mm}; anals, about 45^{mm}. On the bridges there are four inframarginals, of which the inguinal is the largest, and the axillary somewhat the smallest.

This species differs from *B. hatcheri* in the greater thickness of the bones of the carapace and in the shorter lobes of the plastron. It is named in honor of the late Professor Othniel C. Marsh.

Baëna cephalica sp. nov.

Plate XII, Figures 1–3.

The name *Baëna cephalica* is given to a fine skull which belongs to the Yale University Museum, and which was collected in the Laramie deposits of Converse County, Wyoming, by Professor J. B. Hatcher. The specimen bears Professor Marsh's receipt number 2110.

In general form the skull is broad behind, and flat above, with pointed snout. The length from the snout to the occipital condyle is 67^{mm}; to the end of the supraoccipital spine, 74^{mm}. The greatest breadth, just in front of the tympanic chambers, is 65^{mm}. From these chambers the width diminishes to the snout. There is first a convexity in the outline, which terminates at the hinder end of the maxilla; a second and longer one which ends behind the premaxilla, and a third one which ends at the premaxillary symphysis. The flat upper surface of the skull descends each way to the perpendicular sides. The sides of the face about the orbits look upward and outward, as well as forward. The tympanic opening is nearly circular, 19^{mm} in perpendicular and 15^{mm} in horizontal axis. The orbit is circular and small, its diameter being 14^{mm}. The nasal opening, as seen from in front, is somewhat heart-shaped, and is directed upward and forward. From the orbit to the tympanic opening is 24^{mm}; from the nares to the orbit is 10^{mm}.

The temporal region is roofed over, not so extensively as in some undescribed Bridger skulls of the same genus. On each side of the supraoccipital, this roof is excavated as far as a line joining the anterior borders of the tympanic chambers. The hinder end of the postfrontal is interposed between the parietal and the squamosal.

In general, the sutures of this skull are very distinct, but no trace has been found of those between the frontals and the parietals. There are distinct nasals. The prefrontal of each side joins the postfrontal, so that the area of the frontals is excluded from the orbit. The postfrontal is large, having a length of 32^{mm}. The jugal is small, having a length of only 8^{mm} and a height of 15^{mm}. The squamosal forms the hinder border of the tympanic opening. Superiorly it has a thin crest, a relic of the former backward extension of the temporal roof. There is a prolongation of the tympanic chamber into this bone. The lower border of the zygomatic bar is considerably exca-

vated. Seen from the side, the maxilla is convex on its lower border. The premaxillæ are distinct from each other and from the maxillæ. At the symphysis they are only 3^{mm} high, but at their union with the maxillæ, 10^{mm} high. As in the Bridger species, there are distinct lachrymal bones. They occupy the position of the descending portion of the prefrontals of other turtles, coming in contact with the vomer.

As seen from below, the maxilla has a broad masticatory surface, its width from the inner border to the cutting edge being 14^{mm}. The inner border of this surface is furnished by the palatine bone. The latter forms the whole of the outer border of the choana. The masticatory surface does not extend forward on the premaxilla. In front of the choanæ there is a deep groove, which anteriorly expands on the lower surface of the premaxillæ. Postpalatine foramina are present.

The pterygoids come in short contact with the maxillæ. They have distinct ectopterygoid processes. Where the posterior part of the palate is constricted, it is 18^{mm} wide. The pterygoids extend backward to the posterior border of the pedicel of the quadrates, thus separating the latter widely from the basioccipital and basisphenoid. There is a considerable groove on each side between the quadrate and the median bones of the base of the skull. The pterygoids join at the midline for some distance in front of the basisphenoid. On each side of the latter, about the middle of its length, is a foramen.

The pedicels of the quadrates are short. The surface for articulation with the lower jaw is deeply concave from side to side; nearly plane from front to back.

The quadrate bone is notched behind for the passage of the stapedial rod.

There appears to have been a system of epidermal scutes covering the upper surface of the skull. Not all the areas occupied by these can be made out with certainty, but some of them are quite distinct. A pair of these seems to have occupied the space between the orbits. Behind each of these is a smaller one which lies over the hinder border of the orbit. A very large scute, or more probably a pair of them, covers the area of the frontal bones and overlaps on the parietals. The posterior half of this scute or scutes is separated by two scutes occupying the midline. One of these, the anterior, is small and circular; the other is elongated and extends backward on the supraoccipital processes of the parietals. It is, of course, possible that the latter scute was divided along the midline.

The study of this skull confirms the view of Dr. George Baur, drawn from the skull of *Compsemys plicatula*, that there are in the skulls of the Amphichelydia few pleurodiran characters. Nasals are indeed present, but they can hardly be

regarded as distinctive, since there are Cryptodira (Porthochelys) which possess nasals. A short supraoccipital spine is very general among the Pleurodira. The character which especially separates the latter group from the Cryptodira is found in the very broad pterygoids, the posterior ends of which do not separate the quadrates from the basioccipitals. In Baëna, as shown in the present skull and in others from the Bridger beds not yet described, the pterygoids are disposed in the same way as in the Cryptodira.

It appears, in fact, that a considerable number of characters exist in the skulls of Baëna, which belong also to the Athecæ. These are found in the short supraoccipital spine, the large postfrontals, the exclusion of the frontals from the orbits, and the participation of the basioccipital in the formation of the foramen magnum.

The nasals, the lachrymals, and the extensive temporal roof may be regarded as primitive characters.

In Baëna, undoubted pleurodiran characters are seen in the presence of a mesoplastron and in the structure of the cervical vertebræ. The suborder Amphichelydia must thus be regarded as securely founded.

Baptemys wyomingensis Leidy.

Plate XIII, Figures 1–3; Text-figure 2.

Baptemys wyomingensis, Leidy, J., Proc. Acad. Nat. Sci. Phila., 1870, p. 5; Contr. Ext. Fauna West. Terrs., 1873, p. 157, pl. xii, pl. xv, fig. 6.

This species is represented in the Marsh collection by a specimen which was collected in the year 1870, in the Bridger beds, near Millersville, Wyoming. The carapace is almost entire, but somewhat crushed and distorted. The plastron is intact. The nearly complete skull is present; likewise, some of the limb bones. The specimen bears the number 484. It is most valuable on account of furnishing the hitherto unknown skull and the not well-known anterior lobe of the plastron.

When this example is compared with the type some differences are observed, but these are not regarded as of specific value. The most important of these differences is the presence of four, instead of three, inframarginal scutes on each of the bridges.

The only portion missing from the skull is the roof of the orbits and the nasal cavity. This deficiency is fortunately supplied by a skull collected during the year 1903 by the American Museum expedition into the Bridger beds near Fort Bridger.

The skull is wedge-shaped, being broad behind and pointed in front. The length from the snout to the occipital condyle is 67^{mm}; to the end of the supraoccipital spine, 88^{mm}. The

width at the upper border of the tympanic cavity is 58^{mm}. There is no roof over the temporal region, and there is no parieto-squamosal arch. The postorbital arch is but little more than 7^{mm} wide. The zygomatic bar is excavated on its lower border. The interorbital space, as shown by the American Museum specimen, is 23^{mm} wide. The orbits are large, having an antero-posterior diameter of about 20^{mm}. The nares, as shown by the specimen last mentioned, have a perpendicular diameter of 16^{mm}. The upper jaw is convex along its cutting edge, rising in front so as to form a median notch. This edge is sharp throughout its length. In the Yale specimen, the lower jaw conceals a portion of the palate near the cutting edge, but this region is exhibited in the American Museum specimen. Running parallel with the posterior half of the cutting edge, and separated from it by a deep furrow, is a sharp dentated ridge, which has a length of 12^{mm}. When the jaws are closed this ridge fits into a groove in the lower jaw.

The choanæ are far forward. The roof of the mouth is vaulted, not greatly unlike that of Testudo. The vomer appears to have extended backward nearly to the pterygoids. The distance across the palatines at their posterior ends is 20^{mm}. The distance across the constricted portion of the pterygoids is 13^{mm}. There are small postpalatine foramina. The outer border of the palatine bone has not been traced with certainty. In the specimen in the American Museum there appears to be a suture running along the bottom of the groove on the outside of the dentated ridge mentioned above. If this is really the case, this ridge lies on the palatine bone.

The tympanic cavity has its posterior wall open, forming a channel for the passage of the stapedial rod. The sutures between the bones of the skull are closed, and some of them can be traced only with difficulty. There appear to have been no nasals. As shown by the American Museum specimen, the frontals are shut out from the borders of the orbits.

The lower jaw appears to have formed a slight beak in front. The anterior half of the efficient border forms a cutting edge which shears against that of the maxilla. Posteriorly the edge divides so as to produce two ridges which enclose between them a deep groove about 4^{mm} wide. It is this groove which receives the dentated ridge of the palate.

Portions of the hyoid apparatus remain clinging to the base of the skull. This apparatus resembles closely the same organ in *Chrysemys elegans*, and is much unlike that of *Dermatemys*.

Text-figure 2 shows the form of the plastron, and this agrees with that of the specimen in the American Museum. Leidy (Contr. Ext. Fauna West. Terrs., pl. xv, fig. 6) has figured the anterior end of a plastron which is truncated and slightly exca-

vated. This may be an individual variation, or it may indicate a distinct species. In all the known specimens of this species the intergular and gular scutes are absent, and the humerals extend forward to the front of the plastron.

A comparison of the skull of this species with that of *Dermatemys mawii*, as described and figured by Bienz (Rev. suisse de Zool., iii, 1895, p. 61, pl. ii, figs. 1–5) shows that the two are similar in general form and in the absence of a temporal roof. The structure of the upper and lower jaws is quite different in the two genera. In Dermatemys the choanæ are underfloored by the palatal plates of the maxillæ and are pushed well backward. In Baptemys they are far forward in the vaulted palate.

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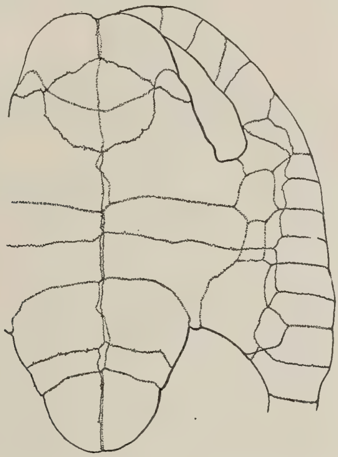

FIGURE 2.—*Baptemys wyomingensis.* Diagram of plastron.

Chrysemys wyomingensis Leidy.

Plate XIV ; Text-figures 3, 4.

Emys wyomingensis Leidy, J., Proc. Acad. Nat. Sci. Phila., 1869, p. 66; Contr. Ext. Fauna West. Terrs., 1873, pp. 140, 340, pl. ix, figs. 4, 5, pl. x, figs. 1, 2. Hay, O. P., Bibliog. and Cat. Foss. Vert. N. A., 1902, p. 448.

In the collection of fossil vertebrates made by Professor Marsh in the year 1874, there is an unusually interesting specimen of turtle. This is a nearly complete shell, and was obtained in the Bridger beds at Millersville, a point a few miles east of Fort Bridger, Wyoming. It is referred without doubt to the species above named. It is interesting from the fact that it possesses a number of supernumerary structures. That is, it has nine neurals, instead of eight; ten pairs of costal

plates, instead of eight pairs ; twelve pairs of peripheral bones, instead of eleven pairs ; six vertebral scutes, instead of five ; five pairs of costal scutes, instead of four pairs ; and twelve pairs of marginal scutes, instead of eleven pairs. There is no doubt regarding the presence of any of these extra bones and scutes, since all the sutures and sulci are very distinct.

A comparison of this carapace with Leidy's figure of *Emys wyomingensis* shows that the whole anterior portion agrees with that figure, only such deviations as might be expected in two individuals of the same species being present. The posterior third, however, leads one into difficulties.

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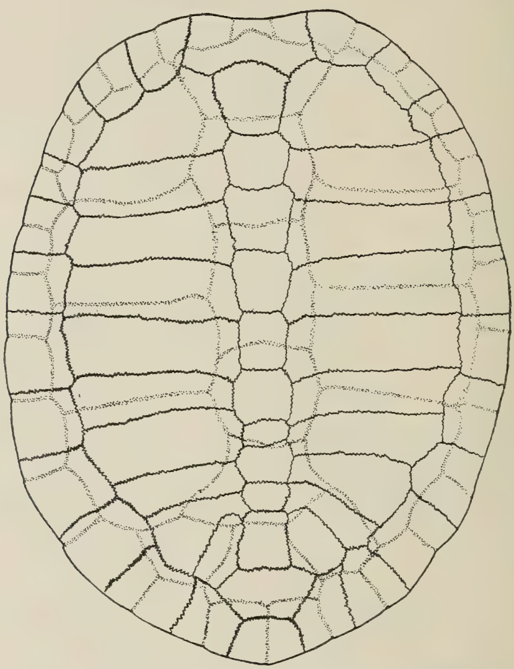

FIGURE 3.—*Chrysemys wyomingensis.* Diagram of carapace of individual possessing supernumerary structures.

The normal number of costal plates is, of course, eight pairs. In some of the living species of North American Trionychidæ the costals are reduced to seven pairs. Dr. Boulenger has stated that in some fossil marine turtles there are nine or ten pairs of costals, but he has not mentioned the species. Such cases may occur, but it is doubtful that they are normal forms. Mr. L. M. Lambe (Contr. Canad. Palaeont., iii, 1902, p. 42, fig. 7) has described as a new genus and species *Neurankylus*

eximius, which has nine pairs of costal plates. Dr. George Baur referred to a specimen of *Malacoclemmys geographica* having nine costals. Dr. Boulenger, in his Catalogue, p. 187, states that in a specimen of Pelomedusa he found nine pairs of costal plates; in another, nine plates on one side and eight on the other. Is it possible, therefore, to determine which costal and peripheral bones, and which vertebral, costal, and marginal scutes, in the specimen at hand, are the intercalated ones?

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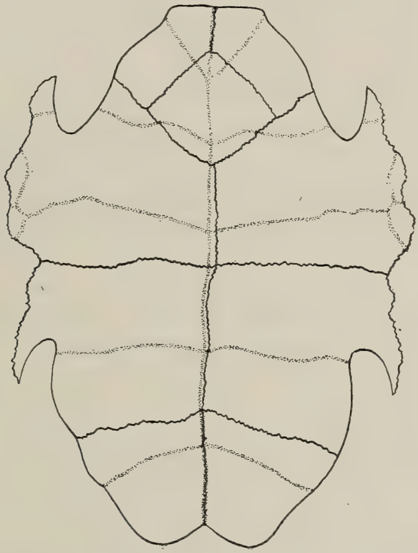

FIGURE 4.—*Chrysemys wyomingensis.* Diagram of plastron of same individual as that of figure 3.

It seems to the writer that there can be no question that the six anterior neural bones and the six anterior pairs of costals, together with the peripherals in contact with the latter, correspond exactly with the six anterior neurals, the six anterior pairs of costals, and the contiguous peripherals, of the type specimen of *Chrysemys wyomingensis*, or, indeed, of any other member of the Emydidæ. It appears to be quite as certain that the seventh pair of costals corresponds with the seventh pair in other emyds. Each is crossed at its upper end by a portion of the longitudinal sulcus, and is in contact with a neural, probably the seventh, and with that behind it.

If, now, one begins at the posterior margin of the shell and works forward, certain conditions may be established. As usual, a pygal peripheral is present. In front of this comes a

broad hexagonal suprapygal, the homologue of which is partly shown in Leidy's figure of the type, and is fully shown by a specimen in the American Museum of Natural History. In all three examples mentioned, this suprapygal is crossed near its anterior end by a sulcus bounding the supracaudal scute in front. In Leidy's type, in front of this suprapygal is another which widens backward. A similar bone is found in the American Museum specimen and in the one here described; but, in both of the latter, the bone is somewhat longer, and is crossed by a transverse sulcus. In Leidy's type, the sulcus crosses on the neural immediately in front,—the eighth.

The last pair of costals in the Yale specimen has all the characteristics of the eighth pair in Leidy's type, and in the American Museum specimen. They come in contact with the two suprapygals, are crossed at their anterior ends by a transverse sulcus, and are occupied in their length by the lateral sulci of the hindermost vertebral scute. In the specimen here described these costals do not indeed come in contact with the hindermost neural; but it is no unusual thing for the last pair of costals to be pushed out of contact with this neural, or the real eighth neural may be suppressed.

It is concluded, therefore, that the intercalated costal plates of the present specimen are the eighth and the ninth from the front of the carapace.

Since there is only one extra neural present, it appears to be impossible to determine whether this is the eighth or the ninth from the front. It may be, however, as already suggested, that the true eighth has been suppressed, and that the eighth and the ninth, counting from the front, are both intercalated.

It is likewise uncertain which is the intercalated peripheral, the tenth or the eleventh of this specimen; but it is more likely the tenth, since it is in contact with both the intercalated costals.

As to the vertebral scutes, the first, second, and sixth seem clearly to correspond with the first, second, and fifth, respectively, of a normal emyd. It appears to be quite as certain that the anterior portion of the fourth corresponds with the same portion of the fourth of any other emyd; and again that the posterior portion of the fifth is homologous with the posterior portion of the fourth vertebral of ordinary turtles. Does not this evidence lead to the conclusion that no new scute has been intercalated, but, rather, that the area occupied by the fourth scute in a normal turtle, having been greatly enlarged, has become divided by a transverse sulcus? In the same way the extra costal scute on each side, as well as the extra marginal, may be explained.

The region immediately in front of the most anterior suprapygal presents various evidences of having suffered disturbance.

Notwithstanding the possession of ten pairs of costal plates, this specimen is not elongated, as one might expect it to be. Indeed, the width is relatively greater than in the specimen in the American Museum.

The plastron appears in no way different from that of the other known specimens of the species. It is quite complete, and a pen drawing showing its structure is here presented.

The total length of the carapace is 325^{mm}; the width is 240^{mm}. Leidy's specimen was at least 330^{mm} long and close to 235^{mm} wide.

Hadrianus majusculus sp. nov.

Plate XV; Text-figure 5.

The shell on which the present species is based was received at the Yale University Museum late in the year 1876. It bears Professor Marsh's receipt number 927. The label has

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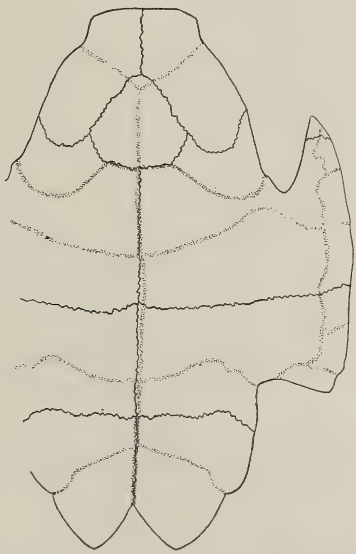

FIGURE 5.—*Hadrianus majusculus.* Diagram of carapace.

the following record: "Turtle from foot of bluff, west side of Murderer's Gap. Nov. 19, 1876. D. Baldwin." Another label states that the specimen came from the "Eocene Bad Lands, Gallina, New Mexico." This locality appears to be in Rio Arriba County, New Mexico. The deposits doubtless belong to the Wasatch epoch.

The upper portion of the shell and one side of it are somewhat damaged. The length of the carapace is 530^{mm}; the greatest breadth was at least 440^{mm}. In form the shell was rather high and vaulted. Over the limbs the peripheral bones are considerably flared upward. The posterior border is rounded and scalloped. The free borders of all the peripherals have acute edges. The form and dimensions of many of the neurals cannot be determined. There appear to have been three suprapygals, the penultimate of which is bifurcate, as in the species of Testudo. The anterior four or five costal plates are alternately narrow and wide, but the proximal and the distal ends of each are of about the same width, thus differing from the costals of Testudo.

The peripheral bones, conspicuously those over the bridges, are much higher than those in the Bridger species, *H. corsoni*. They rise about 90^{mm} above the slight carina which joins the third with the seventh peripheral. The sulci which bound the epidermal scutes are narrow and shallow, but they run in rather deep grooves in the bones. There are two very distinct supracaudal scutes, a right and a left.

The plastron has about the same length as the carapace. There is a distinct lip in front. The rear of the plastron is deeply notched. The antero-posterior extent of the pectoral scutes is considerably greater than in *H. corsoni*.

The large peripherals and the broad pectoral scutes especially distinguish this species from those of Hadrianus hitherto described.

Professor Cope has referred some remains of this genus from the Wasatch of New Mexico to *H. corsoni*, but his specimens were too fragmentary for accurate determination.

Hadrianus majusculus is interesting because of its being the oldest known member of the Chersites, or Testudinidæ.

Testudo brontops Marsh.

Text-figures 6, 7.

Testudo brontops Marsh, O. C., this Journal (3), xl, 1890, p. 179, pl. viii; Vert. Foss. Denver Basin, in Mon. U. S. Geol. Surv., xxvii, 1897, pp. 523, 527, figs. 95, 96. Dana, J. D., Manual Geol., 1896, p. 901, fig. 1516. Hay, O. P., Bibliog. and Cat. Foss. Vert. N. A., 1902, p. 451.

This species has already been briefly described by Professor O. C. Marsh, as cited. The writer has been enabled to study with some care this fine specimen, and here presents diagrammatic figures illustrating the structure of the carapace and the plastron. The structure has been somewhat obscured by crushing, especially along the midline of the carapace.

The length of the carapace is 711^{mm}; the greatest breadth is 651^{mm}. The carapace is truncated in front and broadly

rounded behind. Over the limbs the peripheral bones are considerably flared upward. The sutures separating the nuchal from the first peripherals cannot be traced with certainty. The greatest width of the bone is 175^{mm}; and the length along the midline, 150^{mm}. The first neural bone is oval; the second and fourth, octagonal; the third, hexagonal. The fifth was probably hexagonal, but it is somewhat crushed. The sixth, seventh, and eighth are approximately hexagonal. The anterior suprapygal is bifurcate. The costals of the second, third, fourth,

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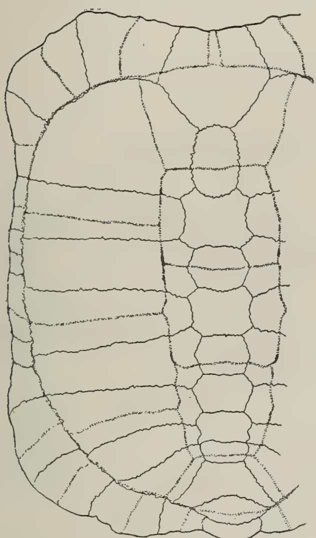

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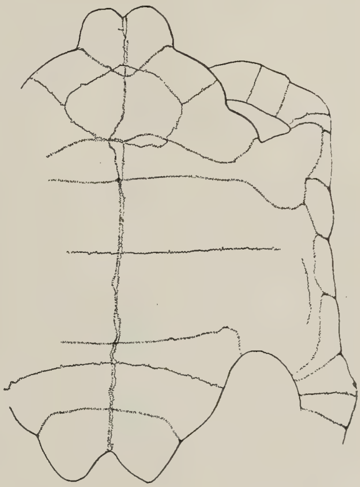

Figure 6.—*Testudo brontops.* Diagram of carapace.
Figure 7.—*Testudo brontops.* Diagram of plastron.

fifth, and sixth pairs are alternately narrow and wide at their proximal ends, and alternately wide and narrow at their distal ends. The following table gives the dimensions of the costals, excluding the first:

Costal.	Width at proximal end.	Width at distal end.
2	56	106
3	100	73
4	56	90
5	94	56
6	61	95
7	40	75
8	43	62

The second and third vertebral scutes had a width of about 190^{mm}. The sulci of the region of the bridge ran in deep valleys, thus giving a scalloped appearance to the border.

The plastron is quite concave. The lip of the anterior lobe projected boldly beyond the general border of the plastron and beyond the front of the carapace. There is a considerable notch in the posterior end of the plastron. The pectoral scutes are about 55^{mm} wide at the midline; the abdominals, 240^{mm}.

This large and fine species was found in the Titanotherium beds of Indian Creek, Pennington County, South Dakota. It is especially interesting because of its being the oldest known species of the genus. Although so old, it appears to have been as highly differentiated in all respects as are the modern forms of the genus.

Aspideretes beecheri sp. nov.

Plate XVI.

Trionyx foveatus Baur, G., Proc. Acad. Nat. Sci. Phila., 1891, p. 418 (not Leidy).

In the Marsh collection there is a fine specimen of a Trionychid to which the above name is given. It was collected in the year 1889 by Professor J. B. Hatcher and Dr. C. E. Beecher, in the Laramie beds of Converse County, Wyoming, on the east side of Lance Creek. The specific name is given in honor of one of the collectors, Dr. Beecher, whose untimely death has wrought such injury to the science of paleontology.

This specimen was examined by Dr. George Baur and identified by him as Leidy's *Trionyx foveatus*. The present writer does not agree with this determination. Dr. Leidy's species was based on rather scant material, but the ornamentation of the costal bones is characteristic and has led to the identification of the species by Mr. L. M. Lambe (Geol. Surv. Canada, Summ. Rept., 1901, p. 81, pls. i, ii; Contr. Canad. Palaeont., iii, 1902, p. 33, pl. i, figs. 1, 2) in finely preserved and quite complete remains. The latter indicate a Trionychid quite different from the one here described.

The type of *A. beecheri* presents the limbs nearly complete, a portion of the neck, the tail, the shoulder girdle, a large portion of the carapace, and the whole of the plastron.

The carapace had a length close to 325^{mm} and a width of 310^{mm}. At each end of the nuchal, the border has been somewhat excavated. The lateral margins are slightly sinuous, and the posterior border has probably been slightly concave.

The outer ends of the nuchal appear to have overlapped the first costal. The nuchal has its whole upper surface covered with a sculpture like that of the costals. There is a preneural bone, whose anterior border has occupied a notch in the hinder border of the nuchal. The author has elsewhere proposed the name Aspideretes for the Trionychidæ possessing a pre-

neural, the type of the proposed genus being *Trionyx gangeticus* Cuvier. The first neural of *A. beecheri* is hexagonal, with the narrow end directed forward. There is present a second neural of similar form and a portion of a third. The remaining neurals are missing. In all probability there were eight pairs of costal plates, but the eighth is represented in this specimen by the free portion only of the corresponding rib.

The sculpture of the carapace consists of a network of ridges enclosing rather deep pits. Usually these pits are without definite arrangement, but on the distal ends of the costals they arrange themselves in rows parallel with the free borders of the carapace. The walls surrounding the pits rise abruptly from the bottoms of the latter; whereas, in *A. foveatus*, the walls slope upward gradually from the centers of the pits. Furthermore, in the latter species, the pits on the proximal ends of the costals are likely to have quite wide flat spaces between them.

The plastron is complete. The entoplastron is truncated in front, with a slight notch at the midline. The branches include between them less than a right angle. The epiplastra are broad at their anterior ends. They resemble greatly the same bones in *Aspidonectes muticus.* The hyoplastra are not coössified with the hypoplastra. Between the inner ends of the hyoplastra is a large fontanelle which is bounded in front by the entoplastron. Between the inner ends of the hypoplastra is another fontanelle which extends backward to the xiphiplastra. There is no fontanelle between the latter bones. The bridge, where narrowest, has a width of 64^{mm}.

The whole lower surface of the hyoplastra, the hypoplastra, and the xiphiplastra, is covered with a sculpture like that of the carapace, except that it is finer.

The cervical vertebra seen in Plate XVI is probably the fifth. Its length is about 60^{mm}. Seven caudal vertebræ are preserved, forming a series 122^{mm} long; but there were others which have been destroyed. They are very similar to those of *Aspidonectes spiniferus.* The shoulder girdle, the fore limbs, the pelvis, and the hind limbs present no important differences when compared with those of modern Trionychidæ.

It appears probable that this individual was a female of mature age.

The U. S. National Museum possesses a Trionychid which was collected by one of Professor Marsh's parties, while he was vertebrate paleontologist to the U. S. Geological Survey. It was obtained in Converse County, Wyoming, and is referred to *A. beecheri.* It shows the carapace to have been high and convex; also, that it had a preneural, six neurals, and eight pairs of costal plates.

EXPLANATION OF PLATES.

Plate XI.

Baëna marshi Hay; view of the plastron. $\times \frac{1}{2}$.

On the left side of the figure is seen a portion of the matrix which filled the shell and from which the bone has been removed. On the opposite side, posteriorly, is seen some matrix filling the inguinal notch. From photograph.

Plate XII.

Baëna cephalica Hay.

Figure 1.—Skull seen from above. $\times \frac{3}{4}$.
Figure 2.—Skull seen from below. $\times \frac{3}{4}$.
Figure 3.—Skull seen from left side. $\times \frac{3}{4}$.

Plate XIII.

Baptemys wyomingensis Leidy.

Figure 1.—Skull seen from above. $\times \frac{3}{4}$.
Figure 2.—Skull seen from below. $\times \frac{3}{4}$.
Figure 3.—Skull seen from left side. $\times \frac{3}{4}$.

Plate XIV.

Chrysemys wyomingensis (Leidy); carapace, showing supernumerary bones and scutes. $\times \frac{2}{5}$. From photograph.

Plate XV.

Hadrianus majusculus Hay; shell seen from the left side. $\times \frac{1}{4}$. From photograph.

Plate XVI.

Aspideretes beecheri Hay; skeleton seen from above. $\times \frac{1}{4}$. From photograph.

Baëna marshi Hay.

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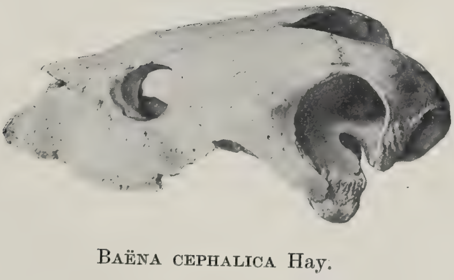

BAËNA CEPHALICA Hay.

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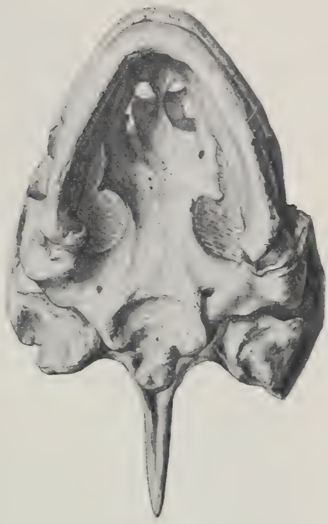

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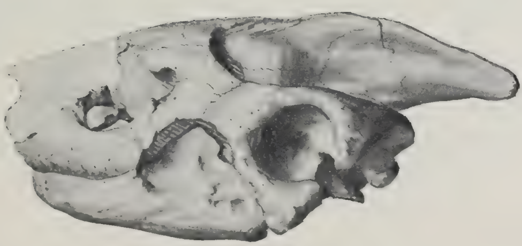
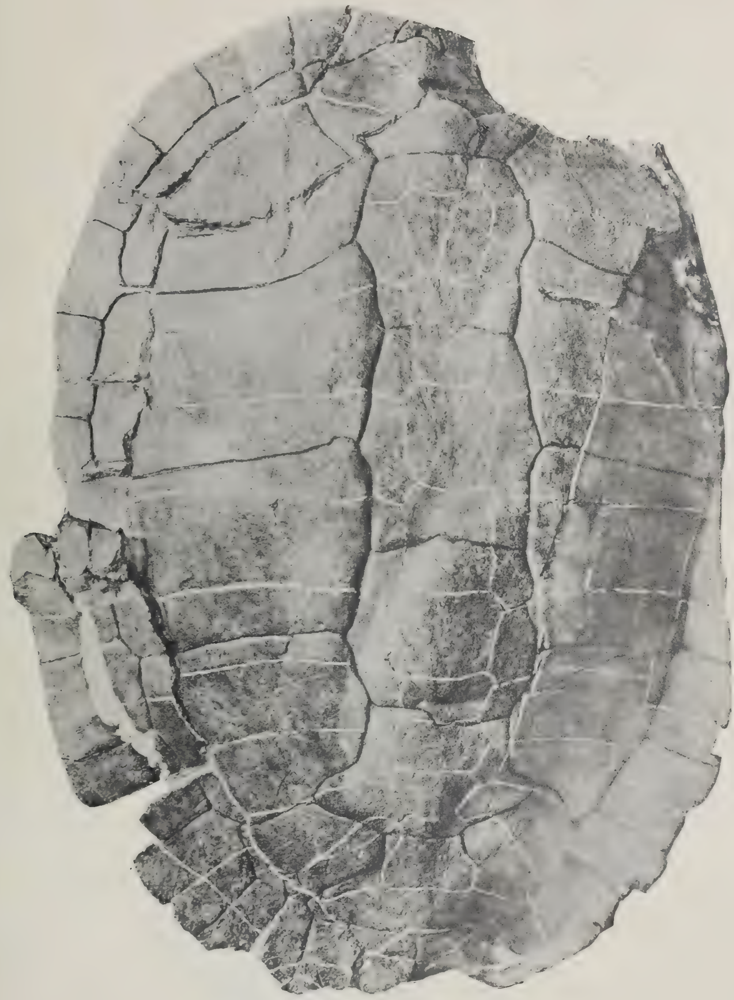
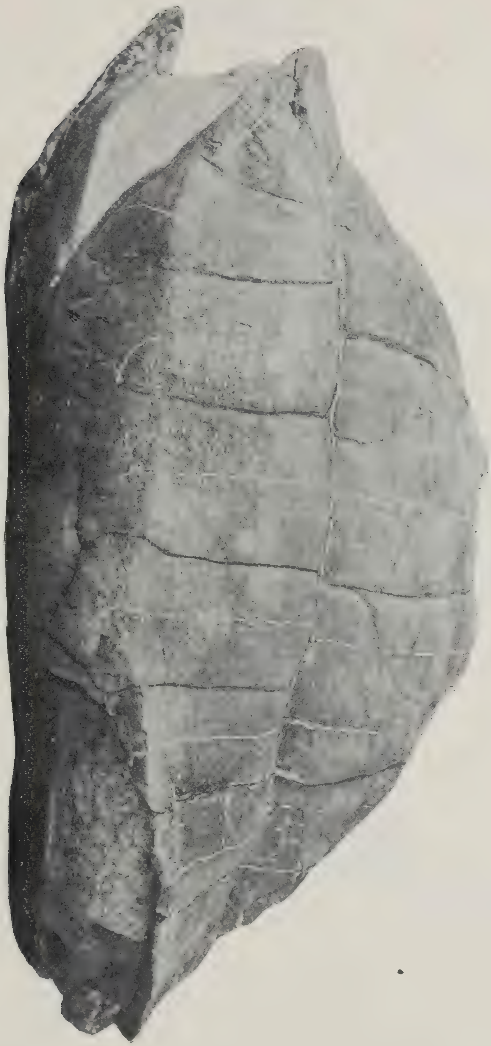


Baptemys wyomingensis Leidy.



Chrysemys wyomingensis (Leidy).



Hadrianus majusculus Hay.

ASPIDERETES BEECHERI Hay.

ART. XXXI.—*Air Radiation;* by C. C. HUTCHINS and J. C. PEARSON.

IN 1892, one of the present writers carried out, at the request of Professor Cleveland Abbe, some experiments for finding the radiation constant of atmospheric air. The radiation was measured from a hot moving column of air of one centimeter depth in the line of sight, and as close as possible, consistent with proper screening, to the heat-recording apparatus. Owing doubtless to defective surroundings, the results obtained from day to day showed considerable variation; in fact, more than could be produced artificially by changing the normal constituents of air in a closed room, such as dust and moisture, between wide limits. An average of the best results gave ·00000114 small calories per second per square centimeter per degree, for a thickness of 1^{cm} of the radiating layer.

In 1900, Professor Very published an extended monograph on the subject, in which very numerous experiments of his own and others are collected and discussed with the utmost skill and patience. Very's result, stated in the terms given above, at 100° excess temperature, was ·00000036, or three times smaller than what we had obtained. The large difference led to a reëxamination of our figures and methods without finding anything that could account for it. An entire change of apparatus and method often leads to unexpected results, and may cause us to modify our views as to the probable error of our former consistent figures. In 1902, we constructed an entirely new apparatus, containing nothing that belonged to the old. A radio-micrometer after Boys was the heat-receiving instrument. We avoided all suspicion of air contamination by taking air from out-of-doors. A box some 6 feet long, 2·5 feet wide, and 3 inches deep, containing a sheet-iron bottom about half-way up, and covered with a single sheet of glass, was set at an angle of about 45° outside a south window. The upper end of the box was extended by a wooden chimney that projected through a slit in the window shutter. The box had trunnions at the sides upon which it could be tilted by pulling a string. The radio-micrometer was mounted inside the shutter, so that in the lowest position of the chimney the current of air that streamed up through came opposite the radio-micrometer opening. Sunlight falling upon the exposed glass cover heated the sheet-iron bottom, and this in turn heated the air in contact with it, and a current of hot air was delivered through the chimney. The temperature of the hot air was obtained by a thermal junction of two thin copper and iron wires inserted in the stream, the circuit being completed through a calibrated galvanometer.

On clear, still days, excess temperatures of 50° to 60° of the hot air stream were obtained, and from the deflections produced as compared with those produced by a lampblacked surface at known temperature, we got values of the radiation constant that lay on both sides of the mean result of 1892. Great difficulty was experienced in getting a steady flow of hot air, and the behavior of the radio-micrometer was far from satisfactory. The experiments were discontinued when it was found that nothing new was to be learned by this method. We could at least conclude that the difference between pure air and that contained in an ordinary room with respect to radiating power was inappreciable.

The winter of 1902–3 was spent in improving the radio-micrometer, and an instrument of remarkable sensitiveness and accuracy was produced.*

This season we have taken up the problem anew with much improved apparatus and in very much improved surroundings. The investigation was carried out in the constant temperature room of the Searles Physical Laboratory, and the extreme range of temperature during the weeks of experiment has been less than 2°.

Finding our knowledge of the absorption of air for its own radiation in a very imperfect state, we turned our attention first to that problem.

Description of Apparatus.

The radio-micrometer was mounted upon a massive stone table, and screened from external sources of radiation. In line with the opening of the radio-micrometer was placed a truncated cone of sheet tin, 45^{cm} long, having an opening $1{\cdot}5^{cm}$ in diameter, corresponding to the opening of the instrument, and enlarging to $5{\cdot}5^{cm}$ at the other end. The cone is extended by a cold-drawn seamless brass tube, polished within, 280^{cm} long, and 5^{cm} internal diameter. Over the end of the brass tube is slipped a tin tube 8^{cm} in diameter, held in place by wooden rings and projecting 70^{cm} beyond the brass tube. These 70^{cm} are thickly set with diaphragms, having 5^{cm} openings, and the tube and diaphragms are carefully blackened. The legitimacy of using reflecting tubes for passing along a radiation from a distant source has often been called in question. All doubt should, however, be set at rest by recent experiments made upon the reflecting power of metals bathed in air, for long waves. Hagen and Rubens show† that all metals are practically perfect reflectors for radiations of great wave length, and it is certain that any difference between the reflecting power for air radiation, which is known to be of very great wave length, and the radiation from a lampblacked surface at slight

* This Journal, vol. xv, April, 1903. † Drude's Annalen, vol. ii, p. 873, 1903.

temperature excess, would be inoperative so far as our present purposes are concerned. Opposite the tin tube is placed the device for heating and delivering an air column. A box of wood 100^{cm} by 35^{cm} by 14^{cm} is mounted upon trunnions so as to be tilted by pulling an attached string. In its vertical position, the column of hot air is delivered centrally past the opening of the long tube, but upon releasing the string the box tilts back out of the way. Beyond the air column stands a large blackened copper cube filled with water at the room temperature, and to this all temperatures are referred.

The box is filled with coils of iron wire which are heated by a current taken from the lighting circuit, and the air flowing up through them is heated in turn. The temperature of the hot air is given by a thermometer having a very small bulb held in the stream at the height of the opening in the long tube.

Experiment to determine the Absorption in the Long Tube for Lampblack Radiation.

As our values of air radiation were to be obtained in terms of radiation from a lampblacked surface, it became necessary to inquire whether the column of air in the long tube exerts any appreciable absorption upon the lampblack radiation. Langley, in his work on the temperature of the moon, has shown that a column of air 110 meters deep absorbs about 20 per cent of the rays from a blackened surface at 100° C. If the absorption follows Lambert's law, it would, in a column of air 245^{cm} deep—the depth used in the following experiment—be about 0·5 of one per cent, and may be neglected. The object of the following was to ascertain if the absorption changes with temperature excess.

A second blackened tank at a higher temperature than the standard tank was thrust in front of the tube and the deflection of the radio-mircometer noted. The following table gives the results.

TABLE I.

Depth of absorbing column, 245^{cm}.

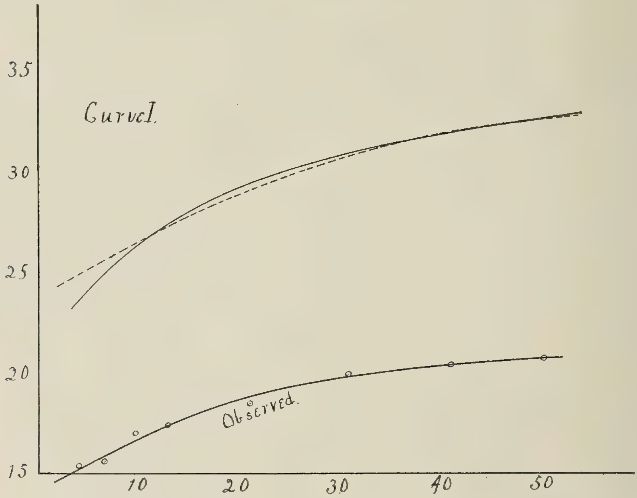
Excess Temp.	Mean Defl.
4°·06	62·6
6·62	103·5
9·55	163·0
12·79	224·0
12·18	51·63
20·91	94·17
30·60	145·3
40·90	200·3
50·00	252·5

The sensitiveness of the instrument was changed by withdrawing the condensing mirror at the point marked by the horizontal line through the table. To reduce all to a common scale, we need a reduction factor for change of sensitiveness. This will be the ratio of the deflection per degree excess for 12°·79 to the deflection per degree for 12°·18, assuming that the radiation rate is the same for these two near temperatures. After applying this factor and dividing each deflection by its corresponding temperature, we obtain the following:

TABLE II.

Excess Temp.	Defl. per Deg. Exc.
4°·06	15·42
6·62	15·63
9·55	17·07
12·79	17·51
20·91	18·61
30·60	20·01
40·90	20·23
50·00	20·86

M'Farlane gives a table* showing the radiation in small calories per second per square centimeter of a blackened surface. For 50° excess, M'Farlane's figure is ·000326. Multiply-



ing the number in the second column of Table II by such a factor as will reduce the last to ·000326, we plot a curve with excess temperatures as values of x, and the observed radiation rates, derived as above, as values of y, and along with it, a second curve from M'Farlane's observations.

* Proc. Roy. Soc, 1872, p. 93.

M'Farlane's curve is dotted. It will be seen that there is nothing shown by the above results from which increased absorption at small excess temperatures can be argued. Considering the widely different methods by which these curves were derived, their agreement is quite striking. We feel sure then that we shall commit no appreciable error in effecting a comparison of air and lampblack radiation if we assume that the latter is unabsorbed by columns of air of the depth used in our experiments. In fact, difference in the manner of preparation of the lampblack surfaces is known to cause greater radiation differences than are shown here.

Absorption of Air for its own Radiation.

The radiation of air cannot be properly considered apart from the question of the rate at which its own radiation is absorbed. Very* obtains a change of deflection per foot of increase in radiating depth of 8·3, 10·0, 8·2, 10·4, –1·2, the depths being 1, 2, 3, 4, and 5 feet, respectively. Disregarding the rather discordant character of these figures, he rejects the negative change for 5 feet entirely on what seems somewhat uncertain grounds. We have sought to avoid the difficulty of absorption in the radiating column itself by measuring the depth of the absorbing layer from the center of a radiating column only 10^{cm} deep; hence if there be any outstanding error, it must be very small and we believe negligible.

A complete example of the method of proceeding is here given. The long tube being in place and carefully covered with asbestos steampipe covering, the current was turned on in the heating box and at the end of half an hour the following deflections were obtained:

TABLE III.

	Defl.	
	55·	
	52·	Date, June 29
	54·5	
	53·	Air column, 491^{cm}
	55·5	
	55·5	Hot air temp. 142°
	52·	
	55·	Room temp. 20·5
	56·	
Mean	54·33	Hot air exc. 121·5

*Atmospheric Radiation, p. 45.

The warmed blackened tank gave the following deflections:

TABLE IV.

Temp. cold tank.	Temp. hot tank.	Deflections.
20·56	24·05	106·
	24·10	101·5
	24·18	109·5
	24·22	106·5
20·58	24·24	104·5
20·57	24·16	105·6

The mean deflection corresponding to 1° excess temperature of air is

$$\frac{54{\cdot}33}{121{\cdot}5}=0{\cdot}4472.$$

The excess temperature of the lampblacked surface is

$$24{\cdot}16-20{\cdot}57+0{\cdot}59=4{\cdot}18$$

where $+0{\cdot}59$ is the thermometer correction. Hence the deflection per degree excess for the lampblacked surface is

$$\frac{105{\cdot}6}{4{\cdot}18}=25{\cdot}26.$$

Finally, the ratio of the hot air radiation to that from the blackened surface is

$$\frac{{\cdot}4472}{25{\cdot}26}={\cdot}01770.$$

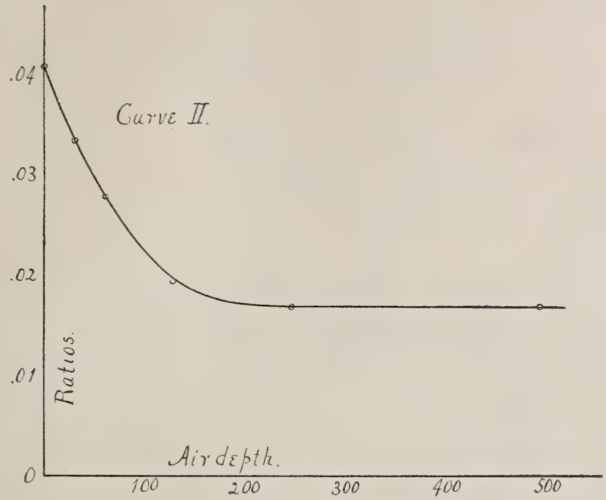
On July 1, we obtained ·159; on July 2, 0·177; on July 8, 0·1734; the average of six days being 0·1685.

The absorbing column was then made 245^{cm}, 127^{cm}, 61^{cm}, and 30^{cm}, and the same method followed for each distance, in each case the observations being distributed over several days. The results are tabulated below:

TABLE V.

Absorbing column	Mean Ratio
30^{cm}	·0332
61	·0278
127	·0195
245	·0169
491	·0168

Plotting these observations with the numbers in the first column of Table V as abscissas and the numbers in the second column as ordinates, we obtain the following curve:



An inspection of this curve reveals a very important feature of air radiation hitherto unknown; namely, that some 60 per cent of its own radiation is absorbed by a column as thin as 245^{cm}, the remaining 40 per cent being freely transmitted as though coming from a black body. We have plotted the ratios of air radiation to lampblack radiation per degree excess temperature. The point where the curve cuts the Y-axis will correspond to the ratio at zero depth of absorbing column, and is important to know. This point may be calculated as follows:

Let L=radiation from lampblack
b=radiation of air for which absorption is neglected
J'=Characteristic radiation from hot air, that is, b neglected

Then at zero depth, $b+J'$ is the total radiation from air. Lambert's law is $J=J'a^b$, and we have plotted the quantity $\frac{b+J'}{L}$ versus d. Taking $d_1=1$, and $d_2=2{\cdot}033$, we have

$$\frac{b+J_1}{L} = 0{\cdot}0332 = \frac{b+J'a}{L}, \tag{1}$$

$$\frac{b+J_2}{L} = 0{\cdot}0278 = \frac{b+J'a^{2.033}}{L} \tag{2}$$

$$\frac{b}{L} = 0{\cdot}0169 \tag{3}$$

We wish to find the value of $(b+J')/L$.

From (3), $b = 0{\cdot}169\ L$

whence, from (1), $J'a = 0{\cdot}0163\ L$

and $a = 0{\cdot}0163\ L/J'$

Substituting the values of a and b in (2), we get

$$0{\cdot}0109\ \mathrm{L} = \frac{(0{\cdot}0163\ \mathrm{L})^{2.033}}{(\mathrm{J}')^{1.033}}$$

whence $$\mathrm{J}' = \mathrm{L}\left[\frac{(0{\cdot}0163)^{2.033}}{0{\cdot}0109}\right]^{\frac{1}{1.033}}$$

This gives $$\frac{b+\mathrm{J}'}{\mathrm{L}} = 0{\cdot}0409.$$

This point fits in a perfectly satisfactory manner upon a smooth curve drawn through the observed points.

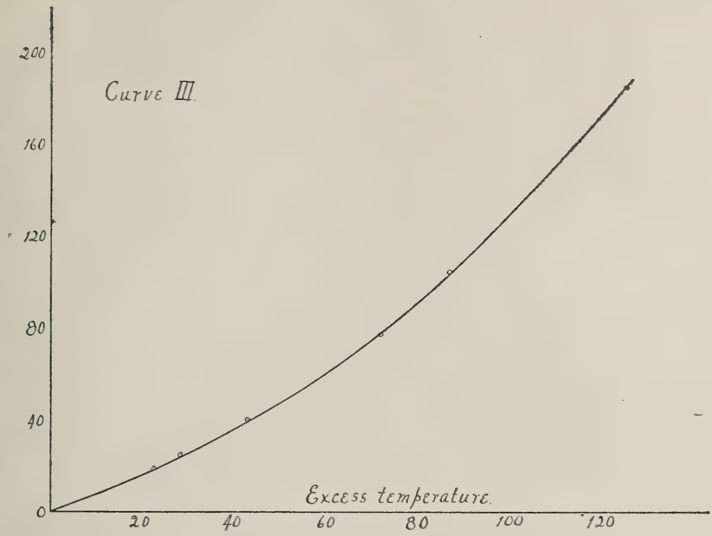
What the course of absorption may be beyond a depth of 500^{cm}, we have no means at present of judging. It may be suggested that the compound nature of air is responsible for its peculiar manner of absorption. Perhaps its contained water vapor is the substance radiating like a black body, and that apart from this, the strongly curved portion of our diagram shows the characteristic behavior of its prominent gaseous constituents. If this be true, it follows that the radiation of pure dry air is effective only at comparatively slight depths. The amount of moisture in the air during this course of experiments was considerable, the relative humidity not varying much from 78·2. It may be that water vapor so little removed from its point of saturation no longer behaves as a true gas, but as an aggregate of particles, in which case it would transmit all rays with considerable freedom, the particles producing a scattering effect merely. The accepted explanation of the color of the sky favors this view.

We have now to discuss the change of radiation of air with change of temperature. By introducing a variable resistance into the circuit of the heating box the temperature of the heated air could be changed at will. A mean of five to ten consistent observations was taken for each temperature and the results tabulated as follows:

TABLE VI.

Exc. Temp.	Mean Defl.
22°·5	18·55
28·2	24·9
43·2	40·9
72·1	77·9
87·0	105·7
125·5	185·9

Plotting deflections versus temperatures from Table VI, we obtain the following curve:



Calling D the deflection and t the temperature, the equation of this curve may be written,

$$D = At + Bt^2 + Ct^3$$

From which, using three observations, we obtain,

$$D = {\cdot}7185\ t + {\cdot}486\ t^2\ (10^{-2}) + {\cdot}96\ t^3\ (10^{-5})$$

the logarithmic coefficients being

$$\log A = 9{\cdot}856448 - 10$$
$$\log B = 7{\cdot}687127 - 10$$
$$\log C = 4{\cdot}984735 - 10$$

From the above the relative ratio of air radiation per degree at different temperatures may be found.

For $t = 1°$, we have $dD/dt = 0{\cdot}728$
For $t = 100°$, $dD/dt = 1{\cdot}98$

Hence the radiation per degree at 100° is $1{\cdot}98/0{\cdot}728 = 2{\cdot}72$ times greater than at 1°.

There remains before computing the value of the radiation constant to find the temperature gradient of the hot air column in the line of sight; laterally, the central portion of the air column only was used and no correction in that direction is required. A thermal junction of thin copper and iron wires was moved by steps through the heated air column, and the readings of a galvanometer, through which the junction was connected, noted. The edge of the opening in the air chimney being called 0, its center would be at 5. The following readings were obtained:

TABLE VII.

Dist.	Defl.
5·0	155
4·0	155
3·0	155
2·0	155
1·0	149
0·5	124
0·2	105
0·0	90
—0·2	75
—0·5	50
—1·0	22

The air flowing up past the outside of the warmed box gave the deflections for negative values of distance; the integral of these was nearly sufficient to balance the loss for less temperature within the range of positive values of the distance. By plotting a curve and integrating the positive and negative values with reference to distance, and radiation rate as derived from Curve III, we find the actual air column to be 0·967 as effective as a column 10^{cm} deep, and at a temperature measured at its center.

We are now prepared to calculate the radiation constant, h. Assume that this is wanted for an excess temperature of 100°, a depth of 1^{cm}, and zero absorbing column. We have:

Ave. of all exc. air temps. observed = 122°
Defl. for 122° from Curve III = 179
" " 100° " " " = 130
Rad. per deg. from lampbl. at 4° exc. (avg.) = ·000249 (M'Farl.)
Ratio of air to lampblack radiation for zero absorbing column, from Curve II, = ·041

Therefore $h = (130/179)\,(\cdot 000249)\,(0\cdot 1)\,(\cdot 041)\,(0\cdot 967)$
$= 0\cdot 000000717$ water-gram-degrees per sq. cm. per sec. per deg. exc. temp.

For 1°, this becomes 0·000000264, and may be found with great facility from the curves given, or from their equations, for any temperature or depth of absorbing column within the limits of our observations.

If our surmise be correct that the freely transmitted part of moist air radiation is from its contained water vapor, amounting to 40 per cent of the whole, then the above numbers would become for dry air, 0·00000043 and 0·00000016, respectively.

Bowdoin College, July, 1904.

Art. XXXII.—*Uintacrinus and Hemiaster in the Vancouver Cretaceous;* by J. F. Whiteaves.

Very few remains of echinodermata have hitherto been found in the Cretaceous rocks of Vancouver and the adjacent islands. Those enumerated in the latest and most complete list of the fossils of these rocks, published by the Geological Survey of Canada in 1902, are only fragments of the test of a regular echinid ; portions of the ray of a five-rayed starfish ; a five-lobed joint of the column of a pentacrinite ; and a fragment of the basal portion of the dorsal cup of a crinoid. Although three of the classes of echinodermata were then known to be represented in these rocks, it was by such fragmentary specimens that it was scarcely possible to determine them, even generically.

But, in a collection of Cretaceous fossils from various localities on or near Vancouver Island, recently sent to the Museum of the Canadian Geological Survey by Mr. Walter Harvey, there are two fairly good specimens of a crinoid, and as many as forty of a spatangoid or heart urchin.

The two crinoids evidently belong to the same species, and are obviously referable to the sessile genus *Uintacrinus*, Grinnell.

One of them is a comparatively large cast of the interior of a dorsal cup, crushed nearly flat, upon a piece of brittle shale from the north bank of the Cowichan River, V. I., about a mile above the bridges at Duncan's, collected by Mr. Harvey in 1903. It is well preserved and shows a monocyclic base, with an undivided centrale, five small basals, five large radials, the third circlet of plates, and a few plates of the fourth. In their shape and arrangement, the whole of these plates correspond very well with those of some regular, monocyclic specimens of the dorsal cup of *Uintacrinus*, as figured in the latest memoir on that genus by the Hon. Frank Springer (1901) and as shown in some fine specimens of *U. socialis* from Kansas, kindly forwarded by Mr. Springer for comparison.

The other specimen is a small, badly preserved and rather worn cast of the interior of a calyx, also crushed nearly flat, from similar shales about a mile south from Vesuvius Bay, Salt Spring Island, in the Strait of Georgia, collected by Mr. Harvey in 1902.

Both of these specimens are clearly referable to the genus *Uintacrinus*, but they are scarcely sufficiently perfect for specific determination or description, though it must be admitted that they show no characters by which they can be

satisfactorily distinguished from some forms of the typical and very variable *U. socialis.*

In Utah and Kansas *Uintacrinus* is said to have been found only in the Niobrara chalk, but the exact equivalent of that subdivision of the Upper Missouri section has not yet been recognized in the Nanaimo group of the Vancouver Cretaceous. The specimens of *Uintacrinus* from Vancouver and Salt Spring islands are from the lower beds of the Nanaimo group, below the coal, and it has yet to be ascertained whether the genus occurs at a little higher geological horizon than the Niobrara at those islands, or whether the supposed lower beds of the Nanaimo group may not at some places represent or include the Niobrara. In the Queen Charlotte Islands the "Upper shales and sandstones, or subdivision A, of Dr. G. M. Dawson's Report" on these islands, which hold *Inoceramus labiatus (problematicus)* are supposed to represent the Niobrara.

The spatangoids are casts of the interior of the test of a species of *Hemiaster*, from shales and sandstones of the Nanaimo group, at four localities on Vancouver Island and one on Salt Spring Island. Many of these casts are distorted and crushed out of shape, but others are well preserved and very little if at all distorted. Two of them, in particular, are almost perfect and very well preserved, and both of these have recently been presented to the Museum of the Canadian Geological Survey. One of them, the first that was obtained, was found by Miss Wilson, in 1897, on the north bank of the Cowichan River, V. I., near Menzies Creek; and the other by Mr. Harvey, in 1903, at Shopland, V. I. Mr. Harvey writes that he has found specimens of this heart urchin all over the Cowichan coal-field, V. I., at the northeast end of Salt Spring Island, and at Crofton, V. I., the most southerly point of the Nanaimo coal-field, in 1902, 1903 and 1904.

Only one species of *Hemiaster* has previously been recorded as occurring in the Cretaceous rocks of North America. This is the *H. Humphreysanus*, from the Fort Pierre or Montana formation of the Upper Missouri country, and district of Athabaska, which was first described by Meek and Hayden in 1857, and re-described and figured by Meek in 1876. But the fauna of the Cretaceous rocks of the Pacific coast is in many respects different to that of their representatives in the great interior plateau, and the Vancouver *Hemiaster* seems to differ from *H. Humphreysanus* in its much more depressed and widely suboval or subovate form. It may be provisionally named and described as follows:

Hemiaster Vancouverensis, sp. nov.

Cast of the interior of the test widely suboval or subovate in marginal outline, a little longer than wide, and widest at or a little in advance of the midlength, with the posterior end abruptly and almost vertically truncated in some specimens but not so much so in others. Dorsal or abactinal surface depressed convex, very slightly elevated, most prominent at a short distance from the posterior end; ventral or actinal surface flattened; greatest height about one-half of the maximum length. Oral aperture not well shown in any of the specimens collected, vent small, a little higher than wide, placed high up on the truncated posterior extremity and near the abactinal surface; apical disc situated at a considerable distance behind the midlength in some specimens, but not very far from median in others. Ambulacra very unequal in length; the odd anterior ambulacrum being a little longer than the anterolaterals, but rather indistinctly defined at the anterior end, and the anterolaterals much longer than the short posterolaterals. Anterior median sulcus shallow but well marked, and giving a faintly emarginate or subemarginate outline to the anterior end. Anterior ambulacrum entirely included within the median sulcus; anterolateral ambulacra petaloidal, narrowly elliptical and shallowly depressed; posterolateral ambulacra also shallowly depressed, somewhat similar in shape to the anterolaterals, but not more than one-half of their length. Spines and exterior of the test unknown.

The foregoing description is based almost exclusively upon the two nearly perfect and undistorted casts from the Cowichan River and Shopland, already referred to, and these may therefore be regarded as the types of the species.

Ottawa, August 23, 1904.

Art. XXXIII.—*The Separation of the most Volatile Gases from the Air without Liquefaction;** by Sir James Dewar.

[Read before the Royal Society of London, June 16, 1904.]

From the time when liquid air came to be an ordinary laboratory agent I have continually used it for the purpose of producing high vacua in vessels that had been previously filled with easily condensable gases, like sulphurous acid, carbonic acid, vapor of water or benzol.

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When the liquefaction of hydrogen was effected, one of the first scientific uses to which it was put was that described in my paper on the "Application of Liquid Hydrogen to the Production of High Vacua, together with their Spectroscopic Examination."† In that communication it was shown by theory and confirmed by experiment that the condensing power of liquid hydrogen is so great relatively to that of liquid oxygen or nitrogen, that any closed vessel, a part of which is cooled to the boiling point of hydrogen, must suddenly become a highly vacuous space. This was proved by the great difficulty of getting electric discharges to pass through specially prepared spectroscopic tubes when subjected to liquid hydrogen cooling, and from the fact that when the current did pass no lines of oxygen or nitrogen were seen, but only those of hydrogen, helium and neon. In order to separate these latter gases from air it was necessary to liquefy a quantity of air and to distill off the most volatile portion at as low a temperature as possible into a separate receiver placed in liquid hydrogen. In this way many spectroscopic tubes were filled with the uncondensable air gases and the results of their examination is recorded in a paper entitled "On the Spectra of the more Volatile Gases of Atmospheric Air, which are not condensed at the Temperature of Liquid Hydrogen,"‡ by Professor Liveing and myself. Some two years later I improved the method of separation of the volatile air gases. The process is fully described and illustrated in my paper on "Problems of the Atmosphere."§ Its success depends upon the continuous direct liquefaction of air at atmospheric pressure combined with a device which

* From an advance proof sent by the author.
† Proc. Roy. Soc., vol. lxiv, 1898.
‡ Proc. Roy. Soc., vol. lxvii, 1900.
§ Proc. Roy. Inst., 1902.

enables the more volatile gases to be trapped and separated. In this way some 1/35,000th of the volume of the air liquefied is collected as a gaseous mixture, having the composition 38 per cent of nitrogen, 4 per cent of hydrogen, and 58 per cent of mixed helium and neon. After sparking to remove the nitrogen and hydrogen a gaseous mixture of helium and neon containing a little argon was obtained. This mixture had the composition of 16 per cent helium and 84 per cent neon. In both methods of treatment it will be noted the liquefaction of the air was the essential preliminary operation, to be supplemented in the one case by the use of liquid hydrogen, in the other by sparking to remove the nitrogen. The paper already communicated to the Royal Society,* entitled "The Absorption and Thermal Evolution of Gases Occluded in Charcoal at Low Temperatures," in which the greatly increased power of occlusion possessed by charcoal at low temperatures is proved, suggested an inquiry into the limits of gaseous pressure reached by such means of condensation.

With this object a narrow tube CE, fig. 1, was sealed to an ordinary spectroscopic sparking tube AB, and at the end E an enlarged space was blown out capable of holding a few grams of cocoanut charcoal. After the charcoal had been freed from gases by heating and exhaustion and the poles cleared by sparking during this operation, pure and dry gases like oxygen, nitrogen, air, carbonic oxide, hydrogen, neon and helium could be admitted at different pressures and the tube with its charcoal chamber attached sealed off.

On placing the charcoal end of the apparatus in liquid air, the gas in each case was rapidly absorbed and the vacuum produced reached the phosphorescent stage in all cases with the exception of hydrogen, neon, and helium. A small Crookes' radiometer, full of air at atmospheric pressure, with charcoal tube attached, became quite active to heat radiation when the charcoal was cooled for half a minute in liquid air. To test the amount of exhaustion reached by the use of a given weight of cocoanut charcoal, I sealed on a tube containing 30 grams to a large electric discharge tube of 1300 c.c. capacity filled with air at atmospheric pressure. On cooling the charcoal receptacle in liquid air the pressure diminished to 50^{mm} of mercury. Repeating the same experiment but starting with the tube initially at half an atmosphere, the exhaustion reached was now beyond the striæ stage. A further experiment starting with one-fourth of an atmosphere gave a vacuum through which no discharge passed.

Finally, the 30 grams of charcoal were replaced by only 1 gram and the initial pressure was reduced to 3^{mm} of mercury.

* This Journal, p. 295 following.

Now the vacuum just reached the beginning of the phosphorescent stage. With hydrogen, either a pressure of gas less than that of the atmosphere had to be used at starting or a larger amount of charcoal employed in order to get a vacuum well up in the striæ stage. If, however, the liquid air was cooled to −210° C. by exhaustion, the tube just reached the beginning of phosphorescence round the cathodes.

With helium there was a very slight absorption, but neon did show something more appreciably. Spectroscopic observations made during the condensation of the gas in the charcoal showed the gradual disappearance of the characteristic spectrum of oxygen, nitrogen and air, as the high vacuum was reached and the discharge passed with great difficulty. In

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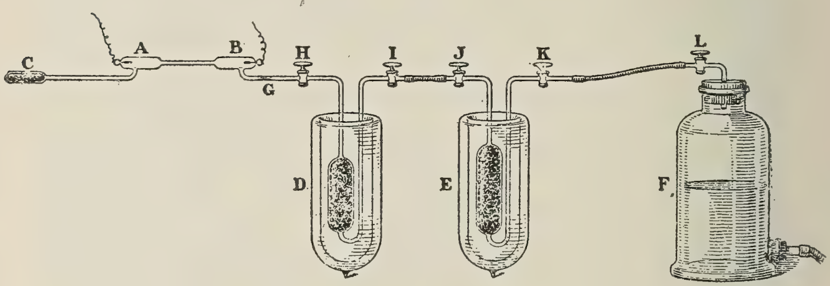


tubes of this kind filled at atmospheric pressure I could always see the F line of hydrogen and the neon yellow; but the helium was not seen with any definiteness. As the amount of neon in the air cannot well exceed 1/50,000th the spectroscopic test is very delicate.

In order to bring in the helium lines it was necessary to concentrate the volume of air in the space of the sparking tube six or seven times. This was done by the use of an arrangement shown in fig. 2. AB is the sparking tube with its small charcoal bulb C attached, capable of being sealed off when required at G; and D and E are larger charcoal absorbers placed in vacuum tubes containing liquid air; the whole being attached to a graduated gas-holder containing air. A series of glass stop-cocks are attached at the points H, I, J and K in order to facilitate manipulation. In determining the volume of air required to bring in the helium lines, only one charcoal absorber containing about 15 grams of material was used. On allowing 200 c.c. of air from the gas holder to be sucked into the charcoal (which had been previously exhausted along with the sparking tube) on opening the stop-cock H any residuary

gas in D was swept into the sparking tube, which was then sealed off at G.

This tube gave the hydrogen lines C and F, the neon yellow, and some of the orange lines, along with the helium yellow and green quite distinct. With the residuary gas extracted from one liter of air I could see all the helium lines. On the positive pole the neon yellow and the green of helium were alone marked, while the negative pole gave both the neon and helium yellow lines along with the helium green and the F of hydrogen on the continuous spectrum. From this it would appear that the spectroscopic test for helium is as delicate as that for neon, and that 1/50,000 can be recognized. From 3 liters of air discharge tubes were obtained, giving the neon and helium spectra associated with a brilliant ruddy glow discharge.

As 40–50 grams of charcoal can absorb at the temperature of liquid air from 5–6 liters, it is easy to accumulate rapidly the uncondensed gases in considerable quantities for spectroscopic examination. For this purpose I found it convenient to use two charcoal condensers in circuit as represented in fig. 2. After the charcoal in the first one marked E was saturated, the stop-cock K was closed, while I and J were opened for a short time so as to allow the less condensable gas in E to be sucked into the second vessel of the same type D along with some portion of air. The charcoal condenser E was then taken out of the liquid air, and rapidly heated to 15° C. in order to expel the occluded air. It was thus in a condition to repeat the absorption. In this way 50 liters of air can be treated in a short time. Sparking tubes filled from the accumulated gases in D were very brilliant, showing the complete spectrum of the volatile constituents of air. It is hardly necessary to remark that after the little charcoal receptacle connected to each of the sparking tubes has been cooled and thus all traces of air absorbed, it can be sealed off, leaving the spectroscopic tubes intact. The complete spectroscopic study of the products must be left for further examination with Professor Liveing.

The method I have described will be equally applicable to the treatment of the gaseous products from minerals containing helium, hydrogen, etc., and also to the radium products of a similar kind. It seems even probable that the separation of the less volatile constituents in air may be improved by a slight modification in the mode of working. The behavior of the gases from the Bath Springs has been examined. When the gas containing 1/1000th part of helium in what may be regarded as pure nitrogen is subjected to charcoal absorption exactly in the same way as the air was treated, no high vacuum

is reached. All the nitrogen and any other constituents disappear, and a spectrum of helium and hydrogen, showing much less neon than exists in the volatile residue from atmospheric air, is the result. A sample of argon made from Bath gas gave, when the argon was absorbed in charcoal, a gas residuum giving the helium and neon spectrum, and the same result follows the use of atmospheric argon. In the case, however, of the Bath gas argon the helium spectrum is the stronger, whereas with air argon the neon is the most pronounced.

In order to further test the method, the crude gases got by heating the mineral fergusonite were examined. During the cooling of the charcoal the nitrogen and hydrogen spectra were marked, but in a short time nothing could be seen but the lines of hydrogen and helium.

Great interest will attach to the behavior of helium, hydrogen and the most volatile part of air, when subjected to the action of charcoal cooled to the temperature of liquid hydrogen. The method promises to open up many avenues for future inquiry.

Art. XXXIV.—*The Absorption and Thermal Evolution of Gases occluded in Charcoal at Low Temperatures;* by Sir James Dewar.*

[Read before the Royal Society of London, June 16, 1904.]

During the year 1874–5, in association with the late Professor Tait, a research was undertaken which involved the production of very perfect vacua, and with the object of improving on the then known methods, dense charcoal was employed as an efficient absorbent of traces of any gaseous residuum. An account of these experiments communicated to the Royal Society of Edinburgh appeared in Nature, July 15, 1875, under the title of "Charcoal Vacua."

In Professor Clerk Maxwell's Notes on "Molecular Physics" the following succinct description of the process is given: "Another method employed by Professor Dewar is to place in a compartment of the vessel a piece of freshly heated cocoanut charcoal, and to heat it strongly during the last stages of the exhaustion by the mercury pump. The vessel is then sealed up, and as the charcoal cools it absorbs a very large proportion of the gases remaining in the vessel.

"The interior of the vessel, after exhaustion, is found to be possessed of very remarkable properties. One of these properties furnishes a convenient test of the completeness of the exhaustion. The vessel is provided with two metallic electrodes, the ends of which within the vessel are within a quarter of an inch of each other. When the vessel contains air at the ordinary pressure a considerable electromotive force is required to produce an electric discharge across this interval. As the exhaustion proceeds, the resistance to the discharge diminishes till the pressure is reduced to that of about a millimeter of mercury. When, however, the exhaustion is made very perfect the discharge cannot be made to take place between the electrodes within the vessel, and the spark actually passes through several inches of air outside the vessel before it will leap the small interval in the empty vessel. A vacuum, therefore, is a stronger insulator of electricity than any other medium."

At one of the conferences held in connection with the Special Loan Collection of Scientific Apparatus† in the year 1876, I showed that with a vapor like bromine the absorptive power of the charcoal was so effective that a space filled with

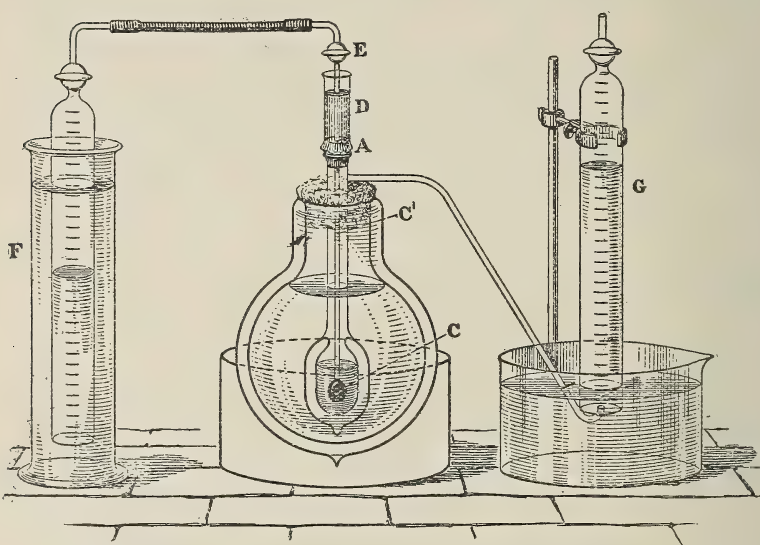
* From an advance proof-sheet by the author.

† See Science Conferences, Physics and Mechanics, p. 154.

the vapor even at atmospheric pressure could be made into a fairly high vacuum showing very wide striæ. When the charcoal was heated the bromine vapor was again expelled, and on allowing it to cool, all stages in the appearance of the electric discharge as the vacuum is reached could be conveniently observed without the use of any form of air-pump.

When in the course of low temperature investigations the perfection of the vacuum vessels for the storage and manipulation of liquid air and hydrogen came to be important, the effect of charcoal on heat isolation in such utensils was fully

1



investigated and confirmed in a paper entitled "Liquid Air as an Analytic Agent."* Still no systematic experiments on the absorptive power of charcoal at low temperatures were made either at this time or subsequently.

It is the object of the present preliminary paper to contribute some definite quantitative data regarding gas absorption and thermal evolution in charcoal at the temperature of liquid air. The mode in which liquid gases like oxygen or air could be used as calorimetric agents was described in my paper on the "Scientific Uses of Liquid Air."†

* Proc. Roy. Inst., 1898.
† Proc. Roy. Inst., 1894.

The apparatus was further improved into the form illustrated and described in Madame Curie's Work, "Recherches sur les Substances Radio-Actives," 2d edition, p. 100, as used for the determination of the heat evolved by radium bromide either in liquid oxygen or hydrogen. Such calorimeters are easily adapted to the simultaneous observation of the volume of any gas absorbed by charcoal, and of the concomitant heat evolution.

For this purpose a small glass bulb C (fig. 1) containing from 0·5–1 gram of charcoal has a long narrow tube C' attached, so that it can be immersed in the liquid oxygen or air in the calorimeter A B, while still allowing a part of the tube to project above the cork A. In order to dry and cool the 40 c.c. of gas, which represents the largest volume taken in by the charcoal in my experiments, a little annular space is arranged at D into which liquid air is poured immediately before the experiment is made.

The charcoal, after being placed in the tube C, is heated to a low red heat and simultaneously exhausted by a good air-pump, and after all the gas has been removed the stop-cock E is closed. In this condition it is placed in the calorimeter.

The experiment is conducted by connecting the end of the tube at E by means of an india-rubber tube with a graduated vessel F containing the gas. When all is ready the stop-cock E is opened, so that the gas may rush into the charcoal, and the heat evolved by its absorption distills off the equivalent quantity of liquid air from the calorimeter, which is measured in the vessel G.

The constant of the calorimeter being known (which with liquid air is about 14·5 c.c. per calory), we get the actual thermal evolution together with the volume of gas absorbed.

The heat correction for the rush of gas into the same exhausted glass bulb without charcoal is small in proportion to the total heat evolved, and the same may be said of the volume correction on account of the cooling of the space external to the charcoal. With a variable material like cocoanut charcoal I have in the calorimetric experiments used the same sample in all cases. The following table embodies the general results per cubic centimeter of charcoal. The gas absorption is given at 0° and 760^{mm}. If the volume of gas absorbed had been measured under the same conditions of pressure at $-185°$ C., then the numbers in Column II would all have to be divided by three.

	I. Volume absorbed. 0° C.	II. Volume absorbed. −185° C.	III. Heat evolved. Gram-calories.
Hydrogen	4 c.c.	135 c.c.	9·3
Nitrogen	15 "	155 "	25·5
Oxygen	18 "	230 "	34·0
Argon	12 "	175 "	25·0
Helium	2 "	15 "	2·0
Electrolytic gas	12 "	150 "	17·0
Carbonic oxide and oxygen	30 "	195 "	34·5
Carbonic oxide	21 "	190 "	27·5

In all cases, it will be observed, the amount of gas occluded has been greatly increased at the low temperature, and the degree of condensation is generally such as we should anticipate from the known physical constants of the gases. The amount of heat evolved is so great as to be in excess of that required for liquefaction in the case of gases like hydrogen, nitrogen, and oxygen. The heat produced when successive fractions of the volume of gas required for saturation are absorbed has yet to be determined. In the time required for the absorption no measureable amount of chemical combination was effected between mixtures of hydrogen and oxygen or carbonic oxide and oxygen in the pores of the charcoal.

Such experiments must be extended to the use of platinized charcoal and other catalytic agents.

Perhaps the most striking result is the great difference in properties exhibited by helium. While resembling the other gases in showing increased absorption at the temperature of liquid air, the absolute amount occluded per unit volume of charcoal is about one-tenth that of the other gases at the same temperature. There can be little doubt that when the relative absorption of helium in charcoal is measured at the temperature of liquid hydrogen, the increased absorption will be so marked as to make it comparable to that of hydrogen in the present set of experiments. In this case charcoal at the boiling point of hydrogen will become an efficient condensing agent for helium, and this property will have important applications in future research.

Separation of Highly Concentrated Oxygen from Air.

In order to examine the changes taking place in a mixed gas like air during the absorption, a quantity of about 50 grams of charcoal was, after heating and exhaustion, saturated at −185° in a current of pure dry air; got by passing the air current through a U-tube immersed in liquid air.

For a time the air rushed into the charcoal with great rapidity, and in about 10 minutes between 5 and 6 liters were taken in.

A manometer attached to the vessel containing the charcoal showed, on shutting off the air current, that during the early part of the saturation the absorption was so effective as to give practically no measurable mercury pressure. As soon as the absorption was ended, and a current began to pass slowly over the charcoal, the composition of the air leaving the charcoal showed 98 per cent nitrogen. After the current of air had passed for half an hour, the total gas occluded in the charcoal was expelled by taking the vessel in which it had been treated out of the liquid air, and allowing the temperature to rise to 15° C.

The gas, which was rapidly expelled, measured 5·7 liters, and contained 56 per cent of oxygen. If the saturated charcoal before heating up was subjected for an hour to the action of an air-pump, capable of giving a steady exhaustion of 5^{mm}, no difference was effected in the oxygen percentage of the evolved gas. The same experiment was repeated with this variation, that, instead of the air current having the pressure of the atmosphere, it was kept below one-tenth of an atmosphere. In this experiment, 4·8 liters were expelled on heating up, and the percentage of oxygen was 58. Then a further repetition was made with an air current supplied at a pressure not exceeding 5^{mm} of mercury. After 3 hours' treatment, the charcoal, on heating to 15° C., gave 4½ liters of 57 per cent oxygen. From these experiments it follows that the tension of the occluded gases, at the temperature of liquid air, must be very small, and thus the use of low temperatures, combined with charcoal, introduces a new and greatly improved means of getting high vacua, which in the future may be found susceptible of important practical applications. These experiments are quite conclusive as to the practical constancy of the mean composition of the air gases occluded in the charcoal (subject to the conditions aforesaid), and they further show that wide changes in the pressure of the air current has little or no effect in altering the proportions. In another experiment, the vessel containing the saturated charcoal, instead of being allowed to rise rapidly in temperature, was transferred to a vacuum vessel, in which a little liquid air was placed, in order that the temperature might rise slowly, and thereby enable the successive liters of gas given off to be collected separately and analyzed. This experiment gave the following results:—

	Oxygen per cent.
First liter	18·5
Second "	30·6
Third "	53·0
Fourth "	72·0
Fifth "	79·0
Sixth "	84·0

The mean composition of the 6 liters is again 56 per cent oxygen. From the above experiments it follows that one of the most rapid means of extracting a high percentage of oxygen from atmospheric air is to absorb it in charcoal at low temperatures, and then to expel it either rapidly or slowly by heating the mass of charcoal to the ordinary temperature.

A few experiments have been made using, instead of air, special mixtures of oxygen and nitrogen. Thus it was found that a gas containing 6·5 per cent of oxygen used in the same manner as in the air occlusion experiments, gave, on heating up the charcoal rapidly to 15° C., 5 liters of gas having the composition of 23 per cent. of oxygen. A repetition of the same process with the 23 per cent of oxygen would have raised the percentage about 60 per cent, or a stronger concentration could have been reached by fractionating the gas as it slowly leaves the charcoal on gradually increasing the temperature.

This preliminary investigation suggests many fields for furture inquiry, and some of these I hope to deal with in future papers.

ART. XXXV.—*Studies in the Cyperaceæ;* by THEO. HOLM. XXIII. The Inflorescence of Cyperus in North America. (With figures in the text.)

A GENERAL consideration of the structure of the inflorescence in *Cyperus* must necessarily result in the conclusion, that throughout the genus the structure is most essentially the same. The components are invariably the same: the involucral leaves, the prophylla, the branches, the floral bracts and the flowers, all these are clearly represented in each species; nevertheless some differences in aspect are frequently quite obvious, but depend to a very large extent simply upon mere variations in the length of the inflorescential branches, in the position of the spikes, their external shape and the manifold structure of the small, floral bracts.—Some of these characters, however, are often deceptive; because in the same species, it is not unusual to meet with individuals in which the number of spikes is reduced to one or two, nearly sessile, with the involucral leaves and prophylla very inconspicuous, while typically developed specimens may possess an ample inflorescence with long leaves and tubular prophylla.

The division of the genus in sections: *Pycreus*, *Cyperus* proper, *Papyrus*, *Diclidium* and *Mariscus*, is not directly based upon deviation in respect to the real components of the inflorescence, but only in regard to the structure of the spikes and the flowers, especially the arrangement and direction of the spikes, the shape of the rhachis and the structure of the achenes. The specific distinction is not materially dependent upon the main inflorescence, inasmuch as the same form is to be observed in remote sections of the genus, but here our attention is directed to the color and minor structure of the spikes, which constitute the ultimate divisions of the inflorescence, also, in some cases, to the structure of the rhizome.

In presenting a brief description of the inflorescence of the genus,we freely admit that we have nothing to add to the old, but most excellent one, given by Fenzl in his paper on *Cyperus Jaquini* Schrad,* or to the more recent one by Clarke,† but we wish to bring out a few points relating to the structure and function of the fore-leaves, which deserve some attention and which ought not to be passed by entirely in systematic treatments of the genus, as has been the case in American literature. It is, furthermore, the writer's desire to demonstrate, that some of the foliar organs which are pres-

*Denkschr. Math.-Naturw. Cl. Akad. d. Wiss., Wien, vol. 8, 1855.
†Journ. Linn. Soc., vol. 21.

FIGURE 1. Inflorescence of *Cyperus phymatodes*, natural size.
FIGURE 2. A prophyllon from the base of a secondary ray of same magnified.
FIGURE 3. Part of the inflorescence of same, magnified. The letters are explained in the text.

ent in the inflorescence of *Cyperus*, are, to some extent, also observable in the panicle of certain *Gramineæ*.

Among the species of *Cyperus*, in which the inflorescence is ample and in which all the foliar organs are well developed and easily distinguishable, *C. phymatodes* Muehl. may be used for illustrating the composition. The accompanying figure 1 represents the upper part of the flower-bearing stem (St.) with the long, leafy bracts (B^1) arranged in a whorl near the apex and supporting secondary branches or rays, as they are often called (R^2), each of which bears a tubular prophyllon or fore-leaf (P^1) at the base.

The flower-bearing stem itself is terminated by a spike (S), borne on a similar ray (R^1) with several lateral spikes besides, but of course destitute of any bract or fore-leaf, since it is terminal. Each of the axillary rays (R^2) bears one pair of nearly opposite rays (R^3), subtended by very small bracts (B^2) and provided with minute fore-leaves (P^2); above these secondary rays (R^3) there is a number of sessile spikes, of which the uppermost is the terminal. By examining these sessile spikes, magnified in our figure 3, it is readily seen that with the exception of the terminal, they are subtended by small bracts (B^2) and that each spike bears a fore-leaf (P^2); moreover this same manner of ramification becomes repeated in the minor inflorescence of third order where the branch (R^3) with its bract (B^2) and fore-leaf (P^2) bears some spikes of third order each with a small bract (B^3) and a fore-leaf (P^3) at the base.—The flower-bearing stem (St. in fig. 1.) is, thus, extended into a short and slender rhachis (R^1) above the involucral leaves (B^1) and this rhachis or ray (R^1) is terminated by a sessile spike (S), overtopping a various number of scattered, sessile and simple spikes, all of which are lateral, being developed from the axils of small bracts, and each bearing a minute fore-leaf at the base. The only difference between this terminal inflorescence (R^1—S) and the larger, lateral ones depends, thus, merely upon these being supported by bracts (B^1) and by the presence of fore-leaves (P^1); these fore-leaves (fig. 2.) correspond to the so-called cladoprophylla, which we have described in a paper upon *Carex*.*

This type of umbellate inflorescence is characteristic of several other genera within the order, and is well represented in certain species of *Scirpus*, *Eriophorum*, *Fimbristylis*, etc. It is, moreover, to be found in *Dulichium*, but with the difference that in this genus the inflorescence, although composed of exactly the same organs, is very long, the internodes between the leaves, which subtend the lateral rays, being developed as distinct internodes, and the subtending leaves being provided

* This Journal, vol. ii, p. 214, 1896.

with long sheaths in contrast to the umbellate inflorescence in *Cyperus* with sheathless, involucral leaves. Otherwise we find in *Dulichium*, as already described, the same fore-leaves though weakly developed, since they are hidden in the sheaths of the bracts, and have not the same function as those in *Cyperus*. The terminal inflorescence in *Dulichium* corresponds to that of *Cyperus*, but is raised high above the lateral ones, on account of these being scattered along the stem and borne on relatively short peduncles.

In speaking of the function of the clado-prophyllon in *Cyperus*, we might state at once, that it is by means of this organ that the rays of the umbel attain their more or less horizontal position. This is readily perceivable when we compare a young inflorescence with an older one. Because it is a well-known fact that before the stamens and pistils are fully developed, the rays and the spikes are all erect and congested. But a little before the flowers are ready for fecundation the rays spread out, forcing the involucral, sheathless leaves to attain the same position, and the spikes themselves gradually bend downwards (*Mariscus*) or horizontally (*Cyperus* proper, *Pycreus* and *Diclidium*) by the swelling of the small, basal prophylla (P^2 and P^3). This movement is best noticeable in the large, tubular prophylla (P^1) at the base of the rays, and we might, thus, briefly describe the structure of these organs in order to show, how the movement takes place. The fore-leaves (fig. 2) are tubular with a short, free apex, and they show, when mature, a very prominent swelling at their base and on that face which morphologically is the dorsal; the swelling, sometimes, attains the dimensions and shape like a spur, while the rhachis itself remains slender in its entire length. It is, thus, on the dorsal face of the prophyllon that a parenchymatic tissue rapidly develops, a tissue which in most respects agrees with true collenchyma; it is composed of short, somewhat thick-walled cells without chlorophyll and no mestome-bundles are located in this tissue. The rapid growth of this particular and very local tissue naturally produces a swelling of the leaf-base, and the result is, that the respective ray becomes pushed away from the central and terminal rhachis of the main inflorescence. (R^1 in fig. 1.) Otherwise the structure of the prophyllon shows no deviations from that of an ordinary leaf-sheath.

Although the base of the ray, which is surrounded by the prophyllon, remains slender, it nevertheless possesses some layers of similar, collenchymatic tissue, the presence of which greatly facilitates the movement from the vertical to the horizontal position, forced by the increased growth of the prophyllon. The small fore-leaves at the base of the spikes

* This Journal, vol. iii, p. 429, 1897.

(P^2 and P^3) show the same structure as the larger ones, but they are more open and only tubular at their very base.

This structure of the clado-prophyllon observed in *Cyperus* is, also, to be found in that of other genera, where the function is identical, but not in *Dulichium* or in certain *Carices* where these fore-leaves are enclosed by the sheaths of the subtending bracts, and where the direction of the rhachis or peduncle remains unchanged.

It is now interesting to notice that the involucral leaves and the clado-prophylla, characteristic of *Cyperus*, etc., may be traced in the inflorescence of certain *Gramineæ*.—Several years ago, when we observed this peculiar structure and function of the prophyllon in *Cyperus*, we naturally felt induced to look for this same organ in the inflorescence of other families, wherein the branches are able to perform the same movement from vertical to horizontal in accordance with the development of the flowers. Our attention became especially directed to the *Gramineæ*, and to such genera in which the inflorescence, the panicle, is ample and rich-flowered. We had already studied the vegetative propagation of this order, the *Gramineæ*, as represented in this country, and we had observed several analogies to exist between these and the *Cyperaceæ*, for instance, the invariable presence of a fore-leaf at the base of each lateral, vegetative branch. We had, also, learned that these fore-leaves are "always" open in the *Gramineæ*, but closed, more or less tubular in the *Cyperaceæ*, a point which explains their identity with leaf-sheaths. Among the *Gramineæ* these fore-leaves (clado-prophylla) are very large and quite numerous in such genera of which the shoots are ramified, and they are readily visible, for instance in *Coix*, *Eleusine*, *Panicum*, *Munroa*, and many others. But if we wish now to demonstrate their presence in the inflorescence also, we are obliged to admit that we have, so far, not succeeded in finding them developed as "free" leaves in any of the numerous species which we have examined for this special purpose. The large and open panicle of several species very often exhibits the presence of rudimentary bracts subtending the lateral branches, but these branches themselves do not possess an independent leaf at their base, which might correspond with the tubular prophyllon (P^1) of *Cyperus*; all that is to be seen is a small cushion-like body, which is located at the base of the secondary branches, and on that side of the branch which turns away from the mother-axis. It is, nevertheless, the peculiar structure of this little body which enables the lateral branches to spread out at a certain stage of the flowering period, and considering the fact that its position answers exactly that of a prophyllon, besides that the bract, which subtends the branch, is, also, present as

a mere rudiment, we have felt inclined to consider these organs: the cushion-like body in the *Gramineæ* and the tubular prophyllon (P') in *Cyperus*, as probably being identical formations.

That the bracts, corresponding with the involucral leaves (B') in *Cyperus*, may be observed in the Gramineæ, has been mentioned by some European agrostologists, and they are quite often developed to such extent that their sheath and blade may be distinguished. In a number of species of *Festuca*, *Bromus*, *Schedonorus*, etc., these little bracts are very distinct, at least at the lower secondary branches of the panicle, but they are seldom free, i. e., the sheath and the apex is mostly adnate to the subtended branch. However in *Panicum proliferum* we have observed one instance where the lowermost bract was provided with a free blade about 20^{mm} in length. The structure of this little bract varies within the respective genera, and may prove useful to the distinction of species, as shown by Lange in *Schedonorus*. But in regard to the supposed clado-prophyllon in the panicle of *Gramineæ*, we have not succeeded in detecting any case where this was developed as an open or free leaf, as are the prophylla of the vegetative branches in this same family. However we have noticed some points in their structure which tend to support our opinion about their real morphological identity, that they represent leaves: "fore-leaves."

These organs are quite large in *Zizania aquatica*, and we have seen one case, where one of these cushions was extended into two free tips, simulating the bidentate apex of a prophyllon. It is, furthermore, to be pointed out that in numerous species, and of the most diverse genera, the external structure of these bodies is like that of the leaf-sheaths: when the stem-leaves, and particularly the sheaths, are hairy, the same kind of hairy covering seems constantly to be observed in these cushion-like organs, and when the sheaths are glabrous these organs are, also, glabrous. Another point which we think deserves notice is, that these same organs never surround the branches, but are always, as stated above, located on the upper face only of the respective branch. Their internal structure suggests that which is characteristic of the fore-leaves in *Cyperus*, since we observed a large mass of collenchymatic tissue, which was not in direct continuation with the tissues of the rhachis itself, but was distinctly separated from the peripheral circle of mestome-bundles and their continuous layers of stereomatic tissue. A series of consecutive sections taken from a secondary branch revealed the fact, that the cushion-like body, even if it be adnate to the rhachis, does not in any place constitute a regularly developed tissue as a portion of the rhachis, but that it represents something supplemental and of which the presence does not influence the structure or arrangement

of the tissues of the rhachis proper. When we compare the structure of this organ and of the rhachis with that of a rudimentary bract and the base of the panicle to which it is adnate and with which it forms one solid body, we then perceive exactly the same conditions in respect to the tissues of the bract being well separable from those of the culm, even if they are united into one body, but of two distinct structures. In other words, the internal structure of the cushion-like body resembles that of a clado-prophyllon in *Cyperus* with its large collenchymatic tissue to such an extent, that as far as concerns the structure alone the organs appear to be identical.

Furthermore when we remember that the fore-leaves of *Gramineæ* are open, the position of this little body in the inflorescence may be well comparable with one of these, since it only covers one, the upper, face of the respective branch. Finally, as we have already stated, the function is, also, the same. We, therefore, believe that the small bodies, always observable at the base of the secondary branches of inflorescences in *Gramineæ*, most distinct in large panicles, that these represent rudimentary prophylla, identical with those described above as characteristic of *Cyperaceæ*.

It would be highly desirable if American agrostologists would reëxamine these organs in our *Gramineæ*, for it may be that some genera or species exist in which they are developed somewhat further and more distinctly as foliar organs. But in regard to our own investigations, we can only say that as far as concerns "position, function and structure" these organs may be regarded as rudimentary leaves or "fore-leaves" in this particular case.

Brookland, D. C., July, 1904.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *Atomic Weight of Beryllium.*—A series of very careful determinations of this atomic weight has been made by C. L. Parsons of New Hampshire College. Two organic compounds of beryllium, the acetylacetonate, $Be(C_5H_7O_2)_2$, and the basic acetate, $Be_4O(C_2H_3O_2)_6$, were used in this work, both of which are easily purified, since they can be readily crystallized from various solvents, and since they possess the additional remarkable property of subliming unchanged. The compounds, after being weighed, were treated with nitric acid in platinum crucibles, and after evaporation the residues were ignited and the resulting beryllium oxide was weighed. Seven determinations by means of the acetylacetonate gave an average result of 9·113 for the atomic weight (where $O = 16$, $H = 1·008$, $C = 12·01$), while nine determinations with the basic acetate gave exactly the same average. The maximum and minimum results were 9·142 and 9·081. The results agree very closely with the atomic weight 9·1 adopted in the "International" table.—*Jour. Amer. Chem. Soc.*, xxvi, 721. H. L. W.

2. *Connection between the Volatility of Compounds and the Forces at Play within the Molecule.*—The view has been brought forward by Geoffrey Martin that chemically unstable compounds are, as a class, characterized by their volatility and fusibility; chemically stable compounds by their involatility and infusibility. For example, $SiCl_4$, BCl_3, $AlCl_3$, $SnCl_4$, etc., are all volatile and also easy to decompose, while the corresponding oxides are far less volatile and less easily decomposed. It is pointed out, further, that high valency compounds are usually more volatile than the corresponding compounds of lower valency; for instance, $SbCl_5$ is more volatile than $SbCl_3$. This behavior is regarded as due to the greater intensity of chemical forces in the lower valency compounds, as compared with the others. It seems, therefore, that it is the internal chemical forces which the atoms exert on each other in the molecule which decide the external attractive force with which the molecules themselves are attracted together, and, therefore, the volatility of the compound. The author believes that the chemical forces within the molecule determine also the solubility, fusibility, hardness, etc., of compounds, and that if these forces were known it might be possible to calculate mathematically the physical properties of chemical compounds.—*Chem. News*, lxxxix, 241. H. L. W.

3. *Method for the Determination of Chloric Acid.*—This determination is usually carried out by reducing the chlorate to chloride and determining the latter by Volhard's volumetric method. The reducing agents heretofore used have been various ones, such as zinc in some form, ferrous sulphate, etc. Hendrix-

SON has found that metallic iron in the form of "card-teeth" in the presence of 10 per cent sulphuric acid effects this reduction rapidly at ordinary temperatures. At first ferric salts are formed and give the solution a yellow color, but these salts are soon reduced and the solution becomes colorless or slightly green. The reduction requires about one hour at room temperature. The process is applicable to bromates, while perchlorates are not reduced by the operation and hence do not interfere with it. Test-analyses are given which show excellent results, and it appears that the method is a very simple and convenient one.—*Amer. Chem. Jour.*, xxxii, 242. H. L. W.

4. *The Investigation of Double Salts by the Determination of Solubility.*—As a continuation of work by the method devised by Professor Foote of the Sheffield Scientific School, FOOTE and BRISTOL have found that barium and mercuric chlorides, below 17·2°, form the double salt $BaCl_2 \cdot 3HgCl_2 \cdot 6H_2O$. Above this temperature no double salt can be crystallized, although there is evidence that combination takes place in solution, because the solubility of each salt is largely increased by the presence of the other. The double salt thus found is a new one. A compound, $BaCl_2 \cdot 2HgCl_2 \cdot 2H_2O$, described by Bonsdorf about seventy-five years ago, does not exist, at least at 10·4°.

FOOTE has found also that the remarkable double nitrate, $2KNO_3 \cdot Ba(NO_3)_2$, described a year or two ago by Wallbridge, is a true double salt, capable of forming under a rather wide range of conditions. He has shown also that no double salt is produced by potassium and barium chlorides at 25°, although the combination of chlorides is far more usual that that of nitrates. —*Amer. Chem. Jour.*, xxxii, 246; 251. H. L. W.

5. *Nitrous Anhydride.*—It has been known for a long time that mixtures of the gases NO and NO_2 condense to a blue liquid, and it has been shown by Lunge and Porschnew that at −20° the composition of the blue liquid formed by saturating liquid N_2O_4 with gaseous NO corresponds very closely to the compound N_2O_3, or nitrous anhydride. This blue compound, consequently, has been regarded as nitrous anhydride, but up to the present time it has not been shown that the compound exists in the solid state, nor that it is the only compound of the two gases. WITTORFF has recently made fusing-point determination with known mixtures of N_2O_4 and NO, and has found that N_2O_3 exists in the form of blue crystals which melt at −103°, and that no other compound was formed at the temperatures used in the experiments.—*Zeitschr. anorg. Chem.* xli, 85. H. L. W.

6. *A Probable Cause of the Yearly Variation of Magnetic Storms and Aurorœ;** by Sir NORMAN LOCKYER and WILLIAM J. S. LOCKYER.—The ordinary meteorological elements, such as atmospheric pressure, temperature, etc., have a yearly change

* From the Proceedings of the Royal Society of London, lxxiv, 90.

satisfactorily explained as due to changes of the position of the earth's axis in relation to the sun, or, in other words, the variation of the sun's declination. There are, however, other phenomena, such as magnetic disturbances and auroræ, which have been explained differently.

Thus, in regard to this seasonal variation Mr. Ellis* has written, "The related physical circumstance is that at the equinoxes, when disturbance is more frequent, the whole surface of the earth comes under the influence of the sun, whilst at the solstices, when magnetic disturbance is less frequent, a portion of the surface remains for a considerable period in shadow."

The object of the present communication is to put forward another possible cause.

It has been previously pointed out† that a very close relationship exists between the epochs of occurrence of prominences in the polar regions of the sun and Ellis's "great" magnetic disturbances. This synchronism showed that either the polar prominences themselves, or the disturbances thus indicated in these polar regions, were the origin of these "great" magnetic storms, or that they were caused by a more general stirring-up of a greater extent in latitude of the solar atmosphere.

A further investigation‡ indicated, however, that in all probability it was either the actual polar prominences themselves, or the activity in the solar polar regions, that initiated these magnetic disturbances, for it was there pointed out that the presence of polar prominence activity-tracks synchronized with the appearances of large "polar" coronal streamers. Here we have an indication of a local cause and effect.

It will be gathered then, that, even as regards terrestrial magnetic phenomena, considerable importance must be attached to action taking place in the regions about the solar poles.

Since the axis on which the sun rotates is inclined to the plane of the ecliptic, there will be times throughout the course of a year when the solar polar regions will be exposed most and least to the earth.

It should be expected, then, that if the polar regions of the sun have any action, as above suggested, the effects of the action on the earth should vary according to the positions of the solar poles relative to the earth.

The actual inclination of the sun's axis being 82° 45′, and the longitude of the ascending node being 74° 25′, or the tilt of the axis being in the direction of about 19 hours in right ascension, it follows that, in each year, the south pole of the sun is most turned towards the earth in the beginning of March (about the 6th), and the north pole most towards the earth in the beginning of September (about the 5th). At the two intermediate epochs,

* Monthly Notices, vol. lxi, p. 540.

† Proc. Roy. Soc., vol. lxxi, p. 244; also Monthly Notices, R.A.S., vol. lxiii, Appendix I, p. 6.

‡ Monthly Notices, R.A.S., vol. lxiii, p. 481.

in June (about 5th) and December (about 6th), neither pole is turned towards or away from the earth, but occupies an intermediate position. Hence we see that the equinoxes occur in the same months as those in which one or other of the solar poles is turned towards the earth, while the neutral positions of the solar poles in relation to the earth occur in the same months as the solstices.

The accompanying diagram [here omitted] shows graphically the relation between the two curves representing the variation of the sun's declination and the change of the latitude of the sun's center or the variation of the amount of the tilt of the solar poles, in relation to the earth throughout a year.

It will be seen that the curve representing the tilt of the solar axis is nearly (a little less than) a quarter of a phase in advance of that indicating the declination change, so that the maximum or minimum point of the latter curve is only slightly in advance of the *mean* points respectively of the former curve.

If, therefore, these solar polar regions are capable of disturbing the magnetic and electric conditions on the earth, as has been above suggested, then, when they are most directed to her at the equinoxes, the greatest effects during a year should be recorded, and when they are least directed the effects should be at a minimum.

It will not be necessary here to refer at any great length to statistics relating to the annual inequality of magnetic disturbances and auroræ, for these have been very efficiently worked out and the results published by Mr. William Ellis.*

Mr. Ellis has shown that the curves of frequency of magnetic disturbances at Greenwich and Paris are very similar, "showing maxima at or near the equinoxes, and minima at or near the solstices." These also, he further points out, are similar, with regard to the epochs of maxima, to the curve representing the frequency of the aurora at London. In the case of auroræ observed in Edinburgh, Northeast Scotland and in different regions in Scandinavia, the months in which the greatest frequency is recorded are September and October (perhaps more generally October) and March and April (perhaps more generally March). Mr. Ellis is inclined to the opinion that there is a small tendency for the autumn maximum to become a little later (from September to October) and the spring maximum somewhat earlier (from April to March) as higher latitudes are approached.

Further, he points out that in more northern latitudes the mid-winter minimum of lower latitudes appears to diminish and eventually disappears, so that the curve of frequency of the aurora between October and March is practically flat with a small intermediate maximum about January. This change in form of the frequency curve in regions in close proximity to the

* Monthly Notices, R.A.S., vol. lx, p. 142; vol. lxi, p. 537; vol. lxiv, p. 229.

magnetic pole, and where the conditions of day and night are so different, is of great interest, but requires careful consideration before it can be regarded as representing real auroral changes.

The accompanying curves [here omitted] illustrate the relation throughout a year between the positions of the earth's poles with reference to the sun ; the positions of the sun's poles as regards the earth ; the frequency of magnetic storms at Greenwich and Paris ; and lastly, the frequency of the aurora as observed at Edinburgh and at stations in Scandinavia below latitude 65° N. The first two curves are those that have already been mentioned, but plotted differently. They have here been so arranged that the maxima points represent the epochs when each of the poles is most inclined to the sun or earth as the case may be. Both the magnetic and auroral curves represent four of the set of curves which Mr. Ellis* has recently published.

It need scarcely be pointed out that the low minima of the auroral curves during the summer months are due in great part to the shortnesss of the nights, and therefore to the restriction of the time available for aurora observations.

The coincidence in time between the epochs of the maxima of the frequency of magnetic disturbances and auroræ, and those of the greatest inclination towards the earth of the north and south solar polar regions is clearly indicated.

It is interesting to inquire in what way this yearly inequality of terrestrial magnetic phenomena is influenced when the sun's polar regions are, for different groups of years, in an undisturbed and disturbed condition.

It would be expected that the oscillation of more disturbed solar polar regions towards and away from the earth would tend to *increase the difference* between the frequency of magnetic disturbance at the equinoxes and solstices, while this difference for those years when the less disturbed solar polar regions are in action should be somewhat *reduced*. That this is actually the case is brought out by the figures which Mr. Ellis has given in the publication of which mention has already been made.

Since the greatest magnetic storms are closely associated in point of time with prominence disturbances in the polar regions of the sun, to make the necessary comparison, therefore, the years in which "great" magnetic storms occurred should be grouped together and the yearly inequality determined, and another group of years in which "great" magnetic storms were less frequent formed and the yearly inequality also determined. Fortunately a computation already made can be utilized for this comparison, for Mr. Ellis has determined the number of days of greater frequency (near sunspot maximum), and lesser frequency (near sunspot minimum), of magnetic disturbance, both groups practically including the conditions required. Thus he has formed groups of the years 1848–51, 1858–61, 1869–72, 1882–85, 1892–95, which include, at any rate for the last three groups, the years where

* Monthly Notices, R.A.S., vol. lxiv, p. 229.

prominences were in high latitudes, and another series of groups of years, 1854–57, 1865–68, 1876–79, 1887–90, which are years when prominences were less frequent in these regions.*

The interesting conclusion to which Mr. Ellis arrived was that "the excess of the equinoctial frequency over the solstitial frequency is greater, the greater the degree of disturbance."

This result thus helps to endorse the suggestion made in a previous paragraph that the greater the disturbed solar polar regions, the greater the difference between the magnetic frequency at the equinoxes and solstices.

Conclusions.—The conclusions arrived at in the above paper may be briefly stated as follows :

1. The seasonal variation in the frequency of magnetic storms and auroræ depends on the position of the sun's axis in relation to the earth.

2. The epochs of the greatest inclinations of the sun's axis towards or away from the earth, or in other words the greatest exposure of the N. or S. solar polar regions to the earth during a year, correspond to those of greatest magnetic and auroral frequency.

3. The epochs (groups of years), when the solar polar regions are most disturbed, synchronize with those when the excess of the equinoctial over the solstitial frequency of magnetic storms is greatest.

7. *Physikalische Technik, oder Anleitung zu Experimentalvorträgen sowie zur Selbstherstellung einfacher Demonstrationsapparate.* Seventh Edition. By Dr. Otto Lehmann. Pp. xx + 630. Braunschweig (Friedrich Vieweg und Sohn).—This is the first part of volume one of Dr. Joseph Frick's well known work. In this edition the book has been entirely rewritten and very much enlarged. In its present form it is an exhaustive compendium treating of the objects, methods and materials of the experimental lecture as a branch of instruction in Physics. This part of the work is concerned with the arrangement of the lecture and preparation rooms and the workshop. All the details of the installations for the electric, gas, water, steam, air pressure and vacuum services and all the non-portable parts of the lecture-room outfit are gone into with the greatest thoroughness. The portion on the shop will be of value to the worker in the laboratory as well as to the lecturer. This part occupies nearly half the book and contains numerous methods, recipes, etc., of use

* The fact that continuous observation of solar prominences was only commenced in 1870 accounts for our lack of knowledge of the frequency of this class of phenomena before that date. Since, however, during the last three sunspot cycles it has been observed that polar prominences are most frequent just a little after a sunspot minimum and up to and at the epoch of the following sunspot maximum, it may be concluded that their appearance previous to the year 1870 occurred at the same time in relation to the sunspot cycle. Ellis's groups of years previous to that date, namely, 1848–51 and 1858–61, may on these grounds be classed as years in which polar prominences were present, whilst the groups 1854–57 and 1865–68 may be taken as epochs when polar prominences were not so frequent.

to the instrument builder, as well as instruction in the arts of forging, soldering, glass-blowing and cutting, lacquering, etc. In addition there are many useful hints on the working and handling of materials such as quartz, amber and porcelain. The camera and dark-room as adjuncts of the lecture, especially the making of slides and the art of photo-micrography, are extensively treated. In fact, one can hardly think of anything in the organization and equipment for this side of physical instruction, from the clerical work of the office to the chemical room, that is not treated. Altogether this is a most valuable book. L. P. W.

II. Geology.

1. *Recent Studies of the Moon's Features* (Communicated by J. Barrell).—Within the past year have appeared two notable contributions to the literature of the moon's surface. One is by Professor N. S. Shaler,* the other by Professor W. H. Pickering† and they represent divergent views. Professor Shaler remarks in the Preliminary Note: "The ends sought have been those alone which had distinct reference to geology. . . In fact almost all the questions brought up by studies on the satellite are more or less entangled with those relating to the evolution of the planet, so that except for the detailed account of the features of either body they must needs be considered together. These features may be compared by types, and in the main the following essay consists of such comparisons."

The craters are so different in size from those of the earth, many being over a hundred miles in diameter, and so numerous, overlapping and irregularly distributed that the causes leading to their formation must be very different from those of volcanoes upon the earth, and for these forms Shaler proposes the name of vulcanoids. The maria, or great plains, evidently belong to a category distinct from the vulcanoids, being characterized by their larger size, smoother and darker floors, and it is suggested that they may be caused by the infalling of large meteors. It would seem, however, that the attempt to provide a meteoric origin for the maria, but not for the craters, would lead into grave difficulties. While the evident fluidity of the lavas which formed them distinguishes them sharply from the steep, rough walls of the vulcanoids, yet in degree of fluidity and in area covered they have not so far exceeded the great lava flows of the western United States and the Deccan of India. The mountainous reliefs

*A Comparison of the Features of the Earth and the Moon, by N. S. Shaler, Professor at Harvard University. Smithsonian Contributions to Knowledge, vol. xxxiv, 79 pp., 24 plates.

† "The Moon, a Summary of the Existing Knowledge of our Satellite, with a complete Photographic Atlas," by William H. Pickering of Harvard College Observatory. 103 pp., 100 plates. New York, Doubleday, Page & Co. The text is a semi-popular treatment of matter already published in vols. xxxii, part I, 1895, part II, 1900 and vol. li, 1903 Annals of the Astronomical Observatory of Harvard College.

are classed under a number of heads, certain wrinkles upon the surfaces of the maria appearing to correspond to the usual earth type of mountains due to crustal shortening; the other types appearing to have had an igneous origin and to be formed of viscous lavas which have solidified with very steep slopes. Clearly marked faults are rare upon the moon, though cracks, as indicated by the so-called "rills," are abundant.

The almost complete absence of evidence of shrinkage and consequent tangential or mountain-making thrust is one of the greatest fundamental distinctions between the history of the earth and its satellite and for a better understanding of which we may have to await a fuller knowledge of the causes of terrestrial contraction.

The ray systems, whitish streaks which radiate from certain of the prominent craters to distances of several hundred miles, crossing plains and vulcanoids alike, are among the most enigmatical features of the moon's surface, becoming strongly visible only about two days after sunrise and disappearing at a somewhat lesser interval before sunset. The author concludes that they are probably fumarolic deposits within and upon the crust from extremely deep-seated fissures and that they are of ancient origin, a view which precludes their consisting of ice, since in that case a gradual evaporation and dispersal of the water vapor would take place at even the lowest temperatures. They are regarded as most probably due to some crystalline and fluorescent material which does not reflect the sunlight until a considerable elevation has been attained.

Considering that these ray systems are of considerable geological antiquity, the author raises the question as to why in a sphere free from erosion they have not become veiled by meteoric dust. Of a number of suggestions presented to explain this feature the most reasonable are that either the amount and importance of meteoric dust received by the earth and moon have been greatly overestimated, or else that we have misjudged the age of the moon's surface and the ray systems are not of great antiquity.

As to the permanence of the lunar relief, it is evident from an examination of the plates "that there is some agent which has operated to break down the more ancient topographical features. There is an evident difference of aspect between the walls of the older vulcanoids and those of newer formation." In fact all stages of obliteration may be traced to large nameless vulcanoids whose ruins only a careful examination will reveal. As water has evidently never acted, the most probable cause is assigned to be alternate expansions and contractions of the superficial crust during the lunar day and night. Whatever the agent of decay may be, the numberless superpositions of vulcanoids and the extremely ruined character of the most ancient is indicative of a long and complex volcanic history. Professor Shaler as the result of his studies disbelieves in any atmosphere or present volcanic activities even of solfataric stages, but in view of the

recent studies to be mentioned later these views may be too extreme. In regard to the question of vegetable life upon the moon it is very properly stated that other possible explanations should be sought to account for the darkening of certain areas at lunar midday in preference to believing them due to vegetable growth. Against the existence of even vegetable life upon the moon it is urged that no terrestrial life exists upon mountain slopes 20,000 feet or more above the sea under atmospheric and thermometric conditions which must be vastly more favorable than those to be found upon the moon. Furthermore, whatever were the circumstances, as yet unknown, which led to the beginning of life upon this earth, they were evidently of rare occurrence. "The fate of our satellite was probably in large part determined by the ratio between its gravitative force and the energy of the kinetic movement of the gases such as constitute the atmosphere. If that energy had been sufficient to retain them on the satellite, there is no reason, at least so long as the original rotation on its axis continued, why it should not have had the history of a miniature earth."

The plates are from photographs in the possession of the Smithsonian Institution and have been taken at the Lick, Paris, and Yerkes Observatories. They are all extremely fine reproductions on several different scales selected with reference to the questions discussed in the text and may be considered as a separate contribution by the Smithsonian Institution to Selenography.

"The Moon," by Professor Pickering, although written in a popular manner, is issued as a scientific book intended for an intelligent class of readers who are not astronomers, and it must be criticized on that basis.

The first three chapters present the commonly accepted views as to the origin of the moon, the data in regard to its distance, rotation, etc., and views arrived at within a few years by the writer and others regarding the density and temperature of a lunar atmosphere.

In another chapter under the subject of artificial craters, the author cites the blow holes formed on the surface of pots of solidifying slag, and also gives the results of experiments upon paraffin, especially where a pumping motion was given to the still molten portions beneath the solidifying crust to simulate subcrustal tidal waves. By this means he was able to obtain the appearance of lunar craters. It may be remarked, however, that even if the craters were all made during that distant time when the moon still retained an axial revolution faster than its orbital revolution about the earth, a conclusion which Pickering himself apparently does not accept, it would be impossible for a solid crust to maintain such rigidity that the lava communicating with a molten interior could rise and fall to an appreciable extent through tidal action. On the contrary, as in the case of the earth, the whole spheroid would yield. This weakness is pointed out by Professor Shaler. The hypothesis is furthermore based

upon the old idea, of an outer crust and a fluid interior, though it has never yet been proved that at any time in the cooling of a planet would such conditions exist.

As it would appear impossible, therefore, to account for the lunar craters by a hypothesis of tidal action upon a fluid interior, it must be confessed that their fundamental differences point to an origin unlike any volcanic features of the earth, and we are still far from an understanding of them.

Under the subject of active lunar craters and river beds, the author describes changes which have been observed in certain lunar craters, which have led him to the belief that volcanic activity has not ceased upon the moon, and that water vapor which immediately turns into clouds of hoar frost is given off from certain craters. In the following chapter it is maintained that the greater brightness of many crater rims and likewise the bright streaks radiating from a number of the principal craters consist of snow.

In the earlier chapter upon the lunar atmosphere, water, and temperature, the author gives good observational grounds for believ ing that an atmosphere exists at the moon's surface, comparable in density to that of the earth at a height of from 40 to 45 miles above the surface. In addition, a haze appears to rise to a height of from three to four miles upon the sunlit side of the moon, but is absent from the unilluminated portion.

Accepting the facts of observation, the extremely questionable side is in the interpretations given them. It has been shown by Stoney that water vapor would escape with great rapidity from the moon and carbon dioxide somewhat more slowly. It would seem extremely improbable, therefore, that these two gases should at the present time be undergoing elimination from the body of the moon, at such a rate as to constitute even such a rare atmosphere as is found or permanent snow fields. Such a hypothesis, while explaining with apparent satisfaction the observed enlargement of the white spots of Linné toward lunar sunset and during a lunar eclipse, as due to a sublimation of hoar frost, is peculiarly difficult of application to the system of rays, and both the atmosphere and rays may consist of some other substances. Until some means is found of proving their nature, some of the suggestions offered by Professor Shaler would appear more reasonable.

Finally in the chapter upon "*Vegetation: the Lunar Canals*," the writer gives his reasons for believing that a luxuriant vegetation exists upon the moon. The evidence for this extreme view is based entirely upon the darkening of certain areas, and their increase of size during the lunar morning, and their disappearance shortly before the time of sunset.

Since conditions so unfavorable to life exist upon the moon, the hypothesis of vegetation should apparently be the last to be sought as an explanation for these mystifying phenomena. An outline of Professor Shaler's criticisms has already been given, and it may be said in addition that for any form of lunar life to

exist not only would it have to originate and evolve into something higher than primordial forms under atmospheric conditions incompatible with life as we know it, but that the conditions of temperature would likewise appear to preclude such a view. While our knowledge of lunar temperatures has been in times past very imperfect, it may be well to quote Professor Very's* more recent and carefully ascertained results. "In conclusion, it seems to me reasonably certain that a large part of the Moon experiences daily great vicissitudes of temperature. Its rocky surface at midday, in latitudes where the sun is high is probably hotter than boiling water; and only the most terrible of Earth's deserts, where the burning sands blister the skin, and men, beasts, and birds drop dead, can approach a noontide on the cloudless surface of our satellite. Only the extreme polar latitudes of the moon can have an endurable temperature by day to say nothing of the night, when we should have to become troglodytes to preserve ourselves from such intense cold."

Although as Professor Very remarks, the noontide temperature may be lower and the life conditions in that regard possibly more favorable than if the moon possessed an atmosphere comparable to our own in density, scientists in general and biologists in particular will be loath to accept a belief in life of any sort upon the moon until at least all other and inorganic hypotheses have been exhausted.

It is regretable that when a scientific volume is put forth for a public who are not specialists, that such doubtful interpretations should be stated as though they were well established and well accepted scientific truths.

The plates show in a systematic manner all visible portions of the moon's surface under five different degrees of illumination, on a scale of $5'' = 1^{mm}$, giving a lunar diameter varying from 14 to 16 inches. As pointed out on p. 97, this is the only complete photographic atlas of the moon in existence, and not only so but it covers the whole visible surface of the moon five times. As the scale is rather small, however, the plates are chiefly useful in studying general features of the moon.

2. *Cretaceous Deposits of the Pacific Coast;* by Frank M. Anderson. Vol II, No. 1, 3d Series, California Academy of Sciences, 146 pp., 12 pls.—The Cretaceous deposits of the Pacific Coast of North America lie within a narrow continental border mainly to the west of the Great Basin and the northern Cordillera. Southward the only deposits of the Pacific province known are isolated ones in Mexico and Chili. In the description of these beds there are given for the first time in a connected account the essential faunal and physiographic facts. The divisions recognized in the Sacramento Basin are:

(1) The Knoxville horizon, several thousand feet in thickness and extending to the upper limit of known species of *Aucellas*,

* The Probable Range of Temperature on the Moon, The Astrophysical Journal, vol. viii, Dec., '98, p. 286.

the fauna being essentially boreal. (2) The Horsetown horizon, beginning with the close of the Knoxville and continuing to the horizon representing the great Chico overlap, the fauna being typically subtropical. (3) The Chico or uppermost member as represented by the Phoenix beds, and by those of Wallala and other points in Lower California. The Chico is divisible into two horizons in the Sacramento Basin, and perhaps elsewhere, the later Chico fauna being characterized by a large development of gasteropods and lamellibranchs.

The general order of regional movement, more particularly in the Great Valley, has been downward from the first, but not continuously so. The different members of the Cretaceous series of California find their counterparts all along the American border of the Pacific, and are to be closely correlated with the recognized members of the interior basins of both hemispheres, as shown by a parallelism of crustal movement and development much more general than commonly supposed, and by extensive faunal resemblances, amounting often to close specific affinity or even specific identity. The faunæ of the Pacific coast Cretaceous are mostly marine, and of littoral rather than deep-sea origin. G. R. W.

3. *Geology of German Southwest Africa.* — At a meeting of the Geological Society of South Africa, held at Johannesburg, July 11th, 1904, Mr. F. W. Voit presented a paper on the geology of the region east of Walfish Bay and between the Quisep and Swakob Rivers.

The country is in large part desert, covered with quicksands and sand dunes. The greater part of the country exhibits the same geological features as the oldest members of the geological formation in South Africa. The base of the district consists of schistose rocks, exhibiting large variety ranging from fine schists to coarsely banded gneisses. These metamorphic rocks are ascribed to the Archean Period. The amphibolite layers in the gneisses are believed to be extrusives of a diabase type. There are also intrusive masses of granite. A few outcrops of sandstone occur and are classed as Lower Devonian. The appearance of copper ore in this district has been investigated by Mr. Voit, and it seems probable that extensive deposits of medium grade ore will be found. It is of interest to note that volborthite (which is elsewhere a rare mineral) is of very frequent occurrence in this district. The rocks collected have been studied microscopically by Professor Beck, of Freiburg.

4. *Liassic and Oolitic Floras of England.*—Being Part II of the Jurassic Flora represented in the British Museum ; by A. C. Seward. 183 pp., 13 pls.—This number of the British Museum catalogue forms the completion of a treatise on fossil floræ of the Trias, Rhætic, Lias, and Oölite of England. Although the fossils included in Part II are for the greater part fragmentary, the high degree of care bestowed on this as on all the parts gives the descriptions importance in themselves aside from the fact that they belong to a series that is indispensable to every student of fossil plants and plant distribution.

Among special features of Part II there perhaps only needs to be here mentioned the fact that two small leaves with a decidedly dicotyledonous appearance are figured (Plate XI, figures 5 and 6) from the rocks of the Great Oölite of Stonesfield, as belonging to the "convenient genus" *Phyllites*. This Seward would have restricted for the designation of Dicotyledonous leaves that cannot with certainty be referred to a particular family.—In commenting on the extremely scanty occurrence of Jurassic dicotyls Seward says, and the reviewer has similarly expressed himself,—"There is, in short, no *à priori* improbability that Dicotyledons existed ages before they attained to a position of importance, and it is highly probable that this was the case." The fundamentally important statement is also made that, "We cannot deduce any evidence from such data as we possess in favor of the existence of well-defined botanical provinces during the Rhætic, Jurassic, or Wealden periods." G. R. W.

III. Miscellaneous Scientific Intelligence.

1. *British Association.*—The annual meeting of the British Association for the Advancement of Science was held at Cambridge during the week from the 17th to the 24th of August. The inaugural address upon the subject* "Reflections suggested by the new Theory of Matter" was delivered by the President, the Right Hon. A. J. Balfour. The attendance at the meeting was 2,789, which has only been exceeded on five occasions. The meeting of next year is to be held at Cape Town, South Africa, and Dr. George H. Darwin has been elected President.

2. *The Metric Fallacy;* by Frederick A. Halsey. *The Metric Failure in the Textile Industry;* by Samuel S. Dale. Pp. 231. New York, 1904 (D. Van Nostrand Co.).—This is a somewhat caustic arraignment of the metric system based upon a paper presented to the American Society of Mechanical Engineers in December, 1902. The authors claim that the actual introduction of the system, in countries where it is sanctioned by law, is less complete than has been supposed, from the standpoint of its practical application in the arts, and give reasons why they believe its introduction in this country to be undesirable.

Scientific workers believe strongly in the simplicity and value of the metric units, but it is fair that the subject should also be discussed from the standpoint of its practical application to the useful arts.

Obituary.

Dr. Joseph D. Everett, for upwards of thirty years Professor of Natural Philosophy at Queen's College, Belfast, died on August 9 at the age of seventy-three years. His excellent translation of Deschanel's Natural Philosophy has been long known and highly valued by students of physics. His book on the C. G. S. system of units, published when the selection of practical units in electricity was under discussion, was an important contribution which has had a wide influence. He was also the author of numerous papers, largely on theoretical subjects.

* See Nature for August 18, also the same number and those immediately following for the addresses by the Presidents of Sections.

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VOL. XVIII. NOVEMBER, 1904.

Established by BENJAMIN SILLIMAN in 1818.

THE

AMERICAN JOURNAL OF SCIENCE.

EDITOR: EDWARD S. DANA.

FOURTH SERIES.

VOL. XVIII—[WHOLE NUMBER, CLXVIII.]

No. 107.—NOVEMBER, 1904.

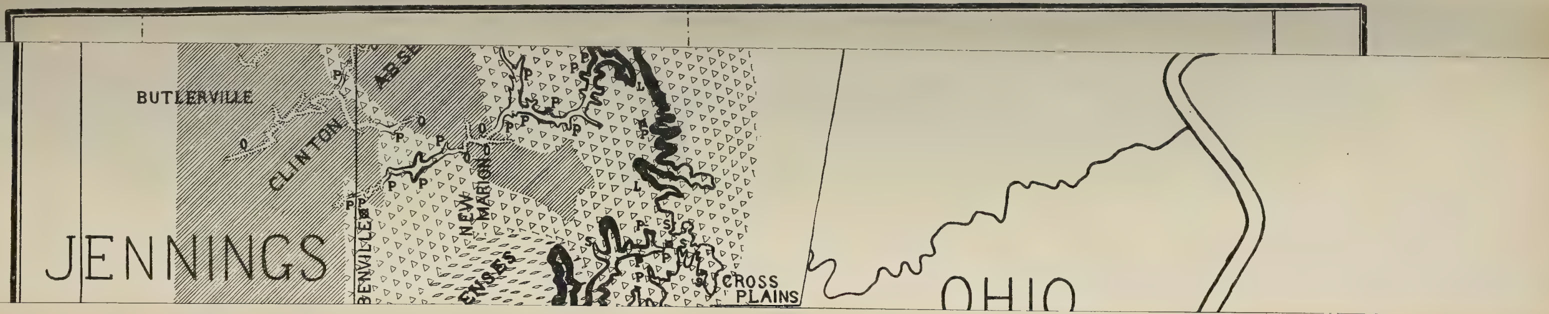
WITH PLATES XVII–XIX.

NEW HAVEN, CONNECTICUT.

1904

THE TUTTLE, MOREHOUSE & TAYLOR CO., PRINTERS, 123 TEMPLE STREET.

Published monthly. Six dollars per year, in advance. $6.40 to countries in the Postal Union. Remittances should be made either by money orders, registered letters, or bank checks (preferably on New York banks).



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THE

AMERICAN JOURNAL OF SCIENCE

[FOURTH SERIES.]

ART. XXXVI. — *The Ordovician-Silurian Contact in the Ripley Island Area of Southern Indiana, with notes on the age of the Cincinnati geanticline;* by AUG. F. FOERSTE. (With Plate XVII.)

Cincinnati Geanticline.

THE axis of the Cincinnati geanticline, a low fold, extends from the northern part of Alabama through central Tennessee and Kentucky into southwestern Ohio and the adjacent part of Indiana. Northward it branches, one axis reaching the western end of Lake Erie,* the other extending northwestward across the northern half of Indiana† into northern Illinois. In Tennessee the rocks dip southeastward as far as Walden Ridge and Cumberland Mountain, a distance varying from 75 to 100 miles; on the western side of the axis the dip is westward or northwestward at least as far as the Tennessee river, a distance of 100 miles; farther west, the Tertiary deposits conceal the Paleozoic rocks involved in the fold. In the southern half of Kentucky the rocks dip westward for a distance of at least 100 miles. From the northern half of Kentucky the dip is westward across the state of Indiana as far as the eastern part of Illinois, a distance approximately of 200 miles. Northward, the rocks dip westward from the western branch of the axis across Indiana and the eastern third of Illinois. Eastward, the rocks dip from the eastern branch of the axis across the state of Ohio as far as western Pennsylvania and the western part of West Virginia, the maximum distance being at least 180 miles.

Over the greater part of the area the dips are too low to be detected from any single point of view. As a rule, however, a comparison of levels of corresponding strata from exposures

* Ohio. Geol. Surv., vi, 1888, map opposite p. 48.
† Indiana Geol. Surv., 18th Rept., 1894, p. 221.

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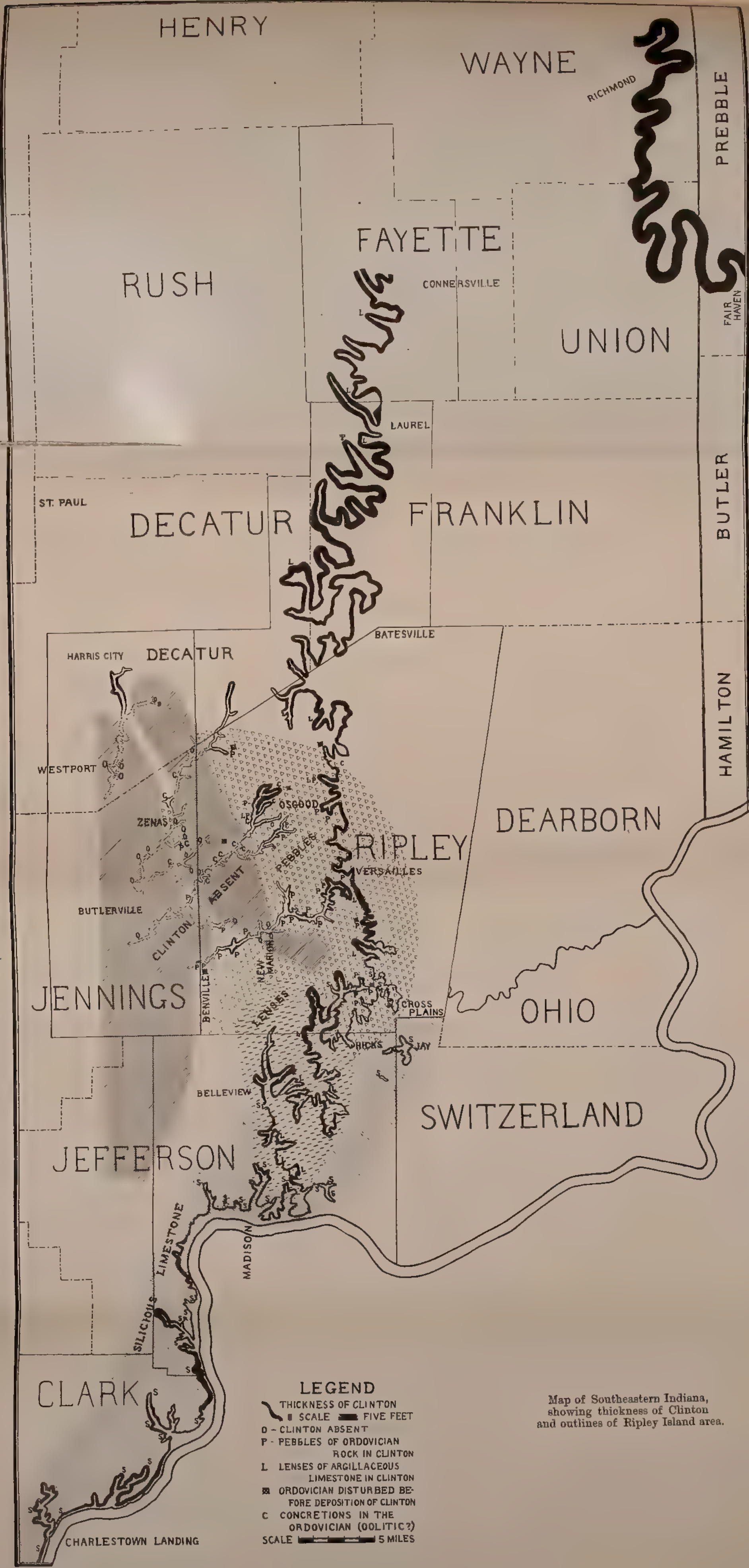


Map of Southeastern Indiana, showing thickness of Clinton and outlines of Ripley Island area.

several miles apart gives unmistakeable evidence of dip. Locally the dips may be conspicuous though rarely exceeding 30 degrees; however, the local nature of these dips is detected easily, and usually is connected with folds and domes of rather small extent. These local folds and domes are much more numerous in the southern half of Kentucky and in Tennessee than in the northern half of the area affected by the geanticline, although tilted rocks are not uncommon along the western branch of the axis in northern Indiana.

The rocks involved in the folding include all of the Paleozoic formations. Ordovician strata are exposed along the greater part of the axis between northern Alabama and a point 26 miles north of Dayton, Ohio, a total distance of 400 miles. In the southern half of Kentucky there is a sag along the axis in consequence of which the crest of the geanticline is formed by Mississippian (sub-Carboniferous) strata. North and south of this sag of the axis, along the crest of the geanticline, are two areas of considerable extent in which the Ordovician exposures are practically continuous. Of these the southern area,* 75 miles long and nearly 50 miles broad, includes all of central Tennessee. The northern area,† 150 miles long and 85 miles broad, includes the northern part of Kentucky and the adjacent parts of Ohio and Indiana, between the towns of Lebanon, Richmond, and Maysville, Kentucky, Dayton, Ohio, Richmond, and Madison, Indiana. That part of the Cincinnati geanticline including the southern Ordovician area is occasionally referred to as the Nashville dome, while the part including the northern Ordovician area is sometimes called the Kentucky uplift or Cincinnati dome. Farther northward in Ohio‡ and Indiana§ the crest of the eastern and western branches of the Cincinnati geanticline is formed by Silurian strata.

Silurian Strata of Geanticline.

No trace of the Lower or Oswegan division of the Silurian, including the Oneida and Medina, is exposed anywhere in the area affected by the Cincinnati geanticline. Middle Silurian or Niagaran exposures, however, ranging from the Clinton to the Guelph, are abundant. Cayugan or Upper Silurian exposures, including rocks formerly known as Waterlime,‖ are known to occur in several areas but have not been studied. In

* Geology of Tennessee, by James M. Safford, 1869, map.

† The Richmond group along the western side of the Cincinnati anticline in Indiana and Kentucky, Am. Geol., 1903, pl. 20; Silurian outcrops indicated by dotted line.

‡ Ohio Geol. Surv., vii, 1893, map.

§ Indiana Geol. Surv., 19th Rept., 1894, map; much more accurate map now in press.

‖ Silurian and Devonian limestones of western Tennessee, Journ. Geol., xi, 1903, pp. 701, 702.

Ohio, Cayugan formations extend from the western Put in Bay islands in the western part of Lake Erie into Lewis county in northern Kentucky, crossing the Ohio river at Vanceburg, Ky. In Indiana, Cayugan strata are known only from Kokomo, although their occurrence in northeastern Indiana has been considered probable.

In Indiana, the Niagaran has been divided into the following subdivisions, named in descending order: Louisville, limestone; Waldron, clay; Laurel, limestone; Osgood, clay and limestone; Clinton, limestone.

Pre-Meso-Devonic origin of the Cincinnati Geanticline.

Along the western flank of the geanticline, in Kentucky and Tennessee, the edges of these subdivisions of the Niagaran, where not covered by overlying subdivisions of the same Niagaran series, thin out eastward toward the Ordovician axis,* and are overlaid unconformably by Middle Devonian limestones or by Devonian black shale. Along the eastern flank of the geanticline, in Kentucky, the uncovered edges of Silurian formations equivalent to the Clinton and Osgood beds thin out in a similar manner westward toward the same Ordovician axis and are also overlaid uncomformably by Middle Devonian limestones or by Devonian black shale. No Silurian rocks are exposed along the eastern margin of the Ordovician area in Tennessee. However, their presence in the Sequatchie valley indicates that Silurian strata exist also along the eastern flank of the geanticline in Tennessee, but are concealed by the cover formed by later strata. The character of the unconformity between the Niagaran and Devonian formations places the origin of the Cincinnati geanticline in times preceding the Middle Devonian.

Pre-Niagaran origin of Geanticline.

Inconclusive nature of certain arguments advanced.—In western Tennessee, Professor Safford and others thought they could trace the upper Niagaran formations up the western flank of the geanticline, farther eastward than the lower Niagaran formations, the former overlapping the latter. From this they concluded that the origin of the Cincinnati geanticline took place in times preceding the deposition of the Niagaran. More recent investigations have not confirmed this overlapping of the upper Niagaran formations, so that this argument becomes ineffective. Other writers have regarded the thinning of the Silurian formations from the flanks toward the crest of the geanticline as sufficient evidence of pre-Niagaran origin.

* Silurian and Devonian limestones of Tennessee and Kentucky, Bull. Geol. Soc. Am., xii, pp. 398, 422. The Cincinnati anticline in southern Kentucky, Am. Geol. 1902, pl. 26; Am. Geol., 1903, pl. 20.

This argument also has lost force since it has been discovered that along the western flank of the geanticline the conspicuous thinning of Niagaran formations toward the east is confined to the edges* of the Niagaran formations, where in succession they project from beneath the immediately overlying Niagaran beds on approaching the crest of the geanticline; and where the thinning of the strata might have been caused by erosion subsequent to their deposition. The same strata fail to show any conspicuous thinning eastward where the immediately following subdivision of the Niagaran is present. Under these conditions it is not possible, without further evidence, to exclude the alternative proposition, that the Niagaran, at least the Clinton and the equivalents of the Osgood clay, originally may have extended across the region of the present Cincinnati geanticline, gradually thinning out westward; that during late Silurian or early Devonian times a geanticlinal uplift occurred, accompanied by removal of Silurian strata along the crest of this uplift and resulting in a conspicuous thinning of the edges of the various Niagaran strata toward the crest of the geanticline whereever exposed by the removal of overlying Niagaran formations. This alternative proposition would demand the operation of geological processes resulting in baselevelling, the Devonian formations being deposited upon the baselevelled edges of the Niagaran. It should be remembered however that, at present, evidence favoring baselevelling of Niagaran strata is confined to the conspicuous thinning of the edges of Niagaran formations toward the crest of the geanticline where not protected by the next overlying Niagaran formations, and the absence of a similar conspicuous thinning in the same direction where the next overlying Niagaran formation is present. It seems scarcely possible that baselevelling could have taken place over areas as large as those exposed along the crest of the Cincinnati geanticline without leaving other evidence than that offered by the thinning of strata as just described.

During the earlier operations of the Geological Survey of Ohio under Professor Orton, thin layers of conglomerate were discovered in the Clinton at Belfast† in Highland county, 57 miles east of Cincinnati, Ohio. The fossils in the pebbles of this conglomerate were believed to have been of Ordovician age, but subsequent investigations proved their Clinton origin, and that older strata of Clinton age had been broken up during the formation of this conglomerate. The presence of conglomerate was believed to be conclusive evidence of the pre-Niagaran origin of the Cincinnati geanticline. It is scarcely neces-

* Silurian and Devonian limestones of Tennessee and Kentucky, Bull. Geol. Soc. Am., 1901, pp. 408–414, fig. 5.

† Ohio Geol. Rept., Surv. for 1870, p. 270. On Clinton conglomerates and wave marks in Ohio and Kentucky, Journ. Geology, iii, 1895, pp. 1–4, 22–26.

sary to point out the inconclusiveness of this evidence founded on observations at a single locality; however in view of opinions as to the age of the Cincinnati geanticline then generally current, the predication of the pre-Niagaran origin of the geanticline on the basis of this Belfast exposure of conglomerate is certainly comprehensible. Moreover, it is not impossible that at some future time, in combination with other evidence not yet at hand, it may prove to have an important bearing upon the subject.

More recent observations upon the Clinton of Indiana have brought to light facts which are of interest in this connection.

Ordovician-Silurian Contact in Ripley Island Area of Southeastern Indiana.

Base of Silurian.—When the investigation of Silurian strata in Indiana was begun, the pre-Silurian origin of the Cincinnati geanticline was accepted. In Ohio the Clinton was known to become thinner westward. Near the Ohio river, in Adams and Highland* counties, exposures equalling 35 feet, in some instances possibly 40 feet, are seen. Northwestward, in Clinton county, the Clinton has a thickness of at least 25, possibly 30 feet. Still farther northwest, east of the Miami river, in the northeastern part of Montgomery and the southeastern part of Miami county, the thickness varies between 23 and 28 feet. Passing from the northern half of this northwesterly running line of outcrop toward the southwest, the rate of diminution of the Clinton is much more rapid. At Sunderland Falls and at Ludlow Falls the thickness is about 22 feet. At Fauvers quarry, 2 miles north of Dayton, west of the Stillwater river, and at Centreville, 9 miles south of Dayton, the thickness is 17 feet. At the Betty Heidy exposure, about a mile east of Oregonia, the thickness is at least 14 feet, and possibly equalled 16 feet. At the Soldiers' Home, west of Dayton, it is about 15 feet. At Lewisburg and Eaton, the thickness is 13 feet. East and southeast of Richmond in Indiana it is about 11 feet. About 12 miles southwest of Eaton, six miles east of the state line, the thickness does not appear to exceed nine feet.

The decrease in thickness of the Clinton toward the southwest continues in Indiana.† Glacial deposits cover the Clinton in the western part of Wayne county, but in the western part of Fayette and Franklin counties the thickness of the Clinton usually does not exceed 6, but occasionally attains 8 feet, and frequently is reduced to 4 feet or even less. Southward, across the center of Ripley county, the thickness of the Clinton con-

* An account of Middle Silurian rocks of Ohio and Indiana, Journ. Cincinnati Soc. Nat. Hist., xviii, 1896.

† Indiana Geol. Surv., 21st Rept. p. 213; and 22nd Rept. p. 195.

tinues to diminish, but southwestward, in the western part of Ripley and the adjacent parts of Jennings and Decatur counties, the Clinton is entirely absent. These facts were entirely unexpected. In keeping with preconceived views of the early, pre-Silurian origin of the Cincinnati geanticline, it was believed that after crossing the axis of the geanticline the thickness of the Clinton would increase instead of decrease westward. Instead, a fairly regular decrease in thickness across the axis of the geanticline was noted, beginning with the most north-eastern exposures in Ohio, and continuing to the most south-western of the series of exposures so far discussed.

The area, or areas, from which the Clinton is absent is here called the Ripley island or islands. The outlines of this area are known only along the eastern border, and even here much remains to be determined. The facts so far discovered are indicated on the accompanying map (Plate XVII). East and southeast of the Ripley island area the Clinton contains pebbles.

These pebbles which occur in the Clinton are usually confined to the lower 4 to 6 inches of the formation. They are commonly not more than an inch in length, although pebbles 2 and even 3 inches in length are recorded from several localities, and at one locality thin flat pieces of rock, 6 to 8 inches in length, were included. Most of these pebbles consist of a very fine-grained white limestone, belonging to the very top of the Ordovician of this part of Indiana. The most common fossil in this white rock is *Tetradium minus*, but this rarely appears in the pebbles. Not infrequently the white limestone occurs directly beneath the Clinton; occasionally in such situations it is cracked and the cracks are filled with the salmon-brown detrital material of which the Clinton is formed in this part of Indiana; the contrast in color is striking. Occasionally the white limestone is cracked also where it occurs at some distance beneath the Clinton and the cracks are filled with clay. Sometimes worm-borings penetrate for several inches into the top of the white limestone, and the cavities are filled with the salmon-brown Clinton material. The pebbles formed from this limestone are frequently very angular in shape, sometimes having the appearance of derivation from some brecciated rock, at other times with the corners conspicuously rounded. It appears that before the deposition of the Clinton, this white limestone was a soft calcareous mud into which worms could bore; owing to shrinkage it cracked into rather small irregular fragments; this shrinkage may have been caused by drying owing to exposure of the surface to the sun; the surface of the Clintonless area may have been in the condition of flats within the reach of high tides; the fragments produced by cracking were often washed toward regions of deposition; those longest exposed to the air

and most hardened, and those transported the shortest distance, were left most angular. Occasionally fragments of Ordovician limestone, formed by the detrital remains of shells and bryozoans comminuted so as scarcely to be recognizable, have been caught up by the Clinton. In these cases the fragments of limestone consist usually of thin slabs. It appears that this limestone of detrital origin solidified more rapidly than the very fine-grained mud forming the white limestone, probably because the detrital limestone permitted a freer circulation of water. In these detrital limestone pebbles *Rafinesquina alternata* and other Ordovician fossils are found. The localities from which pebbles in the Clinton have been recorded are indicated on the map by the letter P; they undoubtedly include only a small part of the localities at which pebbles occur.

South of Laurel, those exposures of the Clinton which indicate a detrital origin usually have a salmon-brown color. The detrital material usually is fairly coarse. The absence of the finer material which must have resulted from the attrition is probable due to currents which were strong enough to sweep along the finer material but left the coarser particles behind to form the Clinton deposit. Sometimes this fine-grained material appears to have been allowed to deposit for a short time, producing thin layers, but as a rule these layers were swept away again later; however their former existence is suggested by the presence in the salmon-brown Clinton of thin lenses of fine-grained whitish limestone, usually widely separated but sometimes connected by very attenuated sheets of the same material. Some of the localities at which these white lenses occur in the salmon-brown Clinton are indicated on the map by the letter L. The lack of distinct bedding or the presence of cross bedding is another evidence of the deposition of the Clinton under the influence of rather strong, irregular currents.

Where the Clinton is absent in Indiana, the lowest layers of the Osgood rest directly upon the Madison bed. At one locality 4 miles west-southwest from Osgood, a single pebble of salmon-brown Clinton rock with blotches of black was found enclosed in the white limestone forming the base of the Osgood beds, 2 inches above the Ordovician. The pebble was 3 inches long, almost 3 inches wide, and half an inch thick. This is the only pebble found at any point in the Osgood bed. Immediately beneath was clay with *Tetradium*, and farther down occurred limestone including concretionary masses or some species of *Strephochetus*.

The presence of areas from which the Clinton is absent, surrounded by areas in which the Clinton contains pebbles of Ordovician origin, is an indication of course of unconformity

between the Silurian and Ordovician in this area. In seeking to determine the measure of the erosion of Ordovician rocks in times preceding the deposition of the Silurian in the Clintonless areas, it was expected that the Silurian would be found to rest upon Ordovician rocks of a considerably lower horizon where the Osgood rested directly on the Ordovician, than at more remote points where the Clinton was present and the pebbles were absent. No striking difference was noted. The detailed observations are presented on the following pages.

Top of Ordovician.—In Indiana, Ohio, and Kentucky, the Cincinnati group at the top of the Ordovician is divided into the Utica, Lorraine and Richmond, named in ascending order. The Richmond is further subdivided into the Waynesville, Liberty, Whitewater, and Madison beds, also named in ascending order. The Madison bed has also been called the Saluda bed, since the name Madison was employed earlier elsewhere. The thickest exposures of the Madison bed are found on the western side of the Cincinnati geanticline, along the Ohio river and thence northward to Laurel, Indiana.

In the neighborhood of Madison,* Indiana, a layer of massive corals, often of large size, has been adopted as marking the base of the Madison bed. These corals are *Columnaria alveolata*, *Columnaria halli*, and occasional specimens of *Calopoecia cribriformis*. *Tetradium minus* occurs 6 feet and, again, 7·5 feet above the massive coral layer, sometimes also 2 feet below the same. Associated with the *Tetradium*, about 6 feet above the massive coral layer, are found *Cyrtolites ornatus*, *Bellerophon capax*, *Lophospira bowdeni*, *Hormotoma gracilis*, *Ischyrodonta miseneri*, *Pterinea demissa*, and a small form of *Platystrophia* with a short hinge line. In the sandy layer immediately above are found *Rhynchotrema capax*, *Strophomena sulcata*, *Strophomena vetusta*, *Dinorthis subquadrata*, *Hebertella sinuata*, *Streptelasma rusticum*, *Streptelasma divaricans*, *Beatricea undulatum*, and a large irregular lobate species of *Heterospongia*. As a rule fossils are scarce at this horizon elsewhere in southern Indiana, with the exception of *Tetradium*, which is quite constant, and often very abundant, at this level.

The lower part of the Madison bed at Madison, 15 feet thick, consists chiefly of clayey rock weathering readily. The greater part of the remainder of the Madison bed, forming a section 32 feet thick, consists of a massive appearing more or less sandy limestone, nearly unfossiliferous, often forming abrupt vertical walls over which plunge the small streams leading to the Ohio. This more massive rock oftens shows color-banding and is the

*Indiana Geol. Surv., 21st Rept. 1897, pp. 248, 249; the lists of fossils by Dr. Cornett and Prof. Cox are in error.

banded rock of earlier surveys, formerly believed to correspond to the Medina of New York.

At the top of the Madison section is a peculiar bluish limestone weathering in a very irregular manner, and containing a considerable fauna which has been only partially studied. Among other fossils may be mentioned *Cyrtocerina madisonense*, *Orthoceras* several species, *Ischyrodonta truncata*, *Ischyrodonta* cf. *miseneri*, *Ctenodonta simulatrix*, *Rhytima* sp. near *oehana* in size, *Byssonychia* several species, *Lophospira hammelli*, *Liospira*, *Holopea hubbardi*, *Labechia ohioensis*, and various species of ostracoda.

On tracing the Madison bed northward from Madison the massive coral bed at the base does not prove to be a conspicuous feature for any great distance, nevertheless in an inconspicuous form it proves constant to its proper horizon as far north as Osgood at least. Here along the stream following the old line of the Baltimore and Ohio Southwestern railroad, about two miles northeast of the town, specimens of *Columnaria alveolata* are rather common immediately below the beds containing *Tetradium*; *Hebertella insculpta*, marking the base of the Liberty bed, occurs just below the junction of this stream with Laughery creek, with the normal vertical interval. At Versailles, however, specimens of *Columnaria alveolata* are rather rare, though some of large size are found occasionally at the proper horizon.

The *Tetradium* bed, on the contrary, often gains in importance northward. At Versailles its thickness is eight and a half feet, *Columnaria alveolata* occurring 16 inches lower down. At Osgood, it rests immediately upon the *Columnaria alveolata* bed. At the Derbyshire Falls, southwest of Laurel, the *Tetradium* bed has a vertical thickness of three and a half feet; *Hebertella insculpta*, marking the base of the Liberty bed, occurs at the proper vertical interval along the road leading from Laurel to Metamora, a short distance south of the crossing over the stream which flows from the Falls to the river.

At Madison, and southward along the Ohio river, the most characteristic part of the Madison bed is the massive sandy brownish rock, 32 feet thick, forming the upper two-thirds of the section. This phase continues northeastward from Madison across the eastern half of Jefferson county. Northwest of this line, however, toward Versailles, New Marion, Butlerville, and northward, there is a considerable change in the lithological appearance of this part of the Madison bed section. The first change is seen 5 miles north of Madison, at the crossing of Razor creek over the Graham road; here the upper part of the section equivalent to the massive brownish sandy bed is more whitish, more calcareous, and less sandy. Two miles farther

north the upper part of the Madison bed, 14 feet thick, is again massive brownish and sandy; the middle and lower part, 40 feet thick, is soft and weathers readily; *Columnaria alveolata* occurs at the base, and *Tetradium* is found 8 feet higher up. A mile and a half farther north, at Belleview, that part of the section equivalent to the upper part of the massive bed, 20 feet thick, is again more calcareous, of a more whitish or bluish color, sometimes slightly tinged with purple; it has a much more calcareous appearance, often weathers very irregularly, and evidently corresponds closely in appearance to the greater part of the Madison bed as exposed at Versailles, New Marion, Butlerville, Nebraska, and northward as far as Osgood and Zenas. This whitish or bluish calcareous form of the Madison bed is the phase most characteristic of the area in which the Clinton is absent, and in the areas immediately adjacent. In this whitish or bluish, more calcareous phase of the Madison bed, fossils, especially bryozoans, are less rare, and at some horizons, especially near the top, are even common locally. That part of the Madison section at Belleview which corresponds to the lower part of the massive division of the section at Madison, retains its brownish, more massive appearance and its practically unfossiliferous character. This part of the section, 15 feet thick, may be traced northward to Versailles, where it forms the unfossiliferous brownish shales, 9 feet thick, immediately overlying the *Tetradium* bed. These unfossiliferous shales occupy the same position along the stream following the old right of way formerly used by the Baltimore and Ohio Southwestern railroad 2 miles northeast of Osgood.

The fauna occurring at the top of the Madison bed at Madison, Indiana, including *Lophospira hammelli*, *Holopea hubbardi*, and other fossils, may be traced northward 2 miles beyond the line between Jefferson and Ripley counties. This fauna is not confined to the top of the Madison bed, but may occur at several levels, although always in the upper part of the Madison bed. Occasionally it occurs in the upper part of the layers which are equivalent to the more massive part of the Madison section, sometimes even 7 feet below their usual horizon. Farther northward, in Ripley county, in the adjacent part of Jennings county, and in the greater part of the area from which the Clinton is absent and within which pebbles are found in the Clinton, the equivalents of the *Lophospira hammelli* and *Holopea hubbardi* beds consists of sandy clays and clayey limestones containing numerous branching bryozoans and also a fair brachiopod fauna. These beds are described in the following paragraphs.

A mile and a half south of Versailles, south of the home of William Rosengarn, the sandy clay at the top of the Madison

bed, 10 feet thick, contains *Byssonychia obesa*, *Ctenodonta cingulata*, a form of *Hebertella occidentalis* in which the median depression of the brachial valve is fairly distinct toward the beak but nearly obsolete anteriorly, a variety of *Platystrophia* of medium size with the hinge line equalling or only slightly exceeding the general width of the shell, *Streptelasma rusticum*, and *Protarea vetusta*.

The same fauna, with the addition of *Schizolopha moorei* and *Streptelasma divaricans*, occurs 2 miles northwest of Versailles, where a branch of Cedar creek crosses the old road from Versailles to Osgood. It is seen also one mile northeast of Osgood south of the right of way formerly occupied by the Baltimore and Ohio Southwestern railroad, in a quarry. Here in addition to the fossils near Versailles are found *Crania scabiosa*, *Trematis millepunctata*, *Hebertella occidentalis* typical form, *Hebertella sinuata*, *Strophomena sulcata*, and *Rafinesquina alternata*. At the quarry the lower part of the section consists of limestone, which is equivalent to the upper part of the massive bed at Madison, and to the upper part of the exposure at the northern edge of Versailles. The overlying section, at least 13 feet thick, contains the fossils just enumerated. Immediately above occur layers of limestone in which are found structures which either are concretionary or are specimens of *Strephochetus* or *Girvanella*, varying between a quarter and a half inch in diameter. This layer is better exposed a quarter of a mile southwest along the same stream, nearer town. Immediately overlying this layer are thin limestones interbedded with clay, a section about 8 feet thick, containing *Hebertella sinuata*, *Platystrophia* Madison bed form, *Strophomena sulcata*, *Lophospira tropidophora*, *Protarea vetusta*, and *Streptelasma divaricans*. Several feet farther up, the top of the Madison bed consists of whitish limestone containing *Tetradium*; it evidently is the source of some of the pebbles in the Clinton limestone.

Six miles north of Osgood, a mile and a half northeast of Napoleon, the clays and thin limestones at the top of the Madison bed, exposed for a distance of at least 10 feet beneath the Clinton, contain *Rhynchotrema capax*, *Zygospira modesta*, and *Plectambonites sericea* in addition to species already mentioned. *Rafinesquina alternata* is rather abundant in the white limestone at the top of the section. *Streptelasma divaricans* is common at this horizon. *Streptelasma rusticum* is less abundant. *Hebertella* near *occidentalis* and the Madison bed form of *Platystrophia* are common here as elsewhere.

A mile north of Napoleon, a branch of Laughery creek exposes the top of the Madison bed, containing *Platystrophia acutilirita*, and a large form of *Plectambonites*, 25^{mm} in width

and strongly curved anteriorly in a geniculate manner, in addition to *Rhynchotrema capax* and other fossils,

The localities so far mentioned occur along the eastern line of outcrop of the Clinton, where the position of the fossiliferous layers, forming the top of the Madison bed, with reference to the *Tetradium* and *Columnaria* layers at its base, may be determined by following these beds along practically continues lines of exposure. The fossil lists indicate the presence in the upper part of the Madison bed of a considerable number of fossils hitherto considered as confined to lower divisions of the Richmond. There is evidently a recurrence of species usually found more abundantly in the Whitewater bed. If the existence of these species at the top of the Madison bed could not be proved by following up practically continuous exposures from Madison to the southeastern border of Ripley county, and then up the Laughery to Versailles, Osgood, and Napoleon, the occurrence of these species immediately beneath the Clinton in the Ripley island area, farther west, at a considerable distance from the continuous line of outcrop, would have been considered as indicative of the presence of one of the lower divisions of the Richmond, probably the Whitewater bed.

Five miles west of Napoleon, a mile southeast of the northwestern corner of Ripley county, on Honey creek, *Leptaena rhomboidalis*, *Strophomena vetusta*, the Richmond group form of *Cyclonema bilix*, and *Calymmene callicephala* are added to the list of species already mentioned as occurring at the top of the Madison bed. *Rafinesquina alternata* is found in the white limestone, 3 feet thick, forming the top of the Madison bed. Immediately below, *Calymmene callicephala*, *Plectambonites sericea*, and a strongly convex species of *Dalmanella*, only 13^{mm} wide, occur. The underlying beds, consisting of thin irregular limestones weathered into fragments and of greater quantities of clay, contain in addition to species already named from this locality, *Hebertella occidentalis*, *Hebertella* near *sinuata*, the Madison bed form of *Platystrophia*, *Platystrophia acutilirita*, *Strophomena sulcata*, the large strongly curved form of *Plectambonites*, *Rhynchotrema capax*, *Protarea vetusta*, *Streptelasma rusticum*, *Streptelasma divaricans*, and *Lophospira tropidophora*. The form of *Byssonychia* usually listed as *B. radiata* is present. The total thickness of the fossiliferous section here is 20 feet. This in itself would formerly have placed the reference of the Honey creek exposure to the top of the Madison bed in doubt, but the fossiliferous layers at the top of the Madison bed northeast of Osgood have an equal thickness, and the exposures at Osgood and near Napoleon carry practically the same fauna.

At Zenas, 5 miles southwest of the Honey creek exposures, the fossiliferous layers at the top of the Madison bed contain

Hebertella near *occidentalis*, and *Hebertella* near *sinuata*, *Platystrophia* Madison bed form, *Platystrophia acutilirita*, *Rafinesquina alternata*, *Ctenodonta cingulata*, *Schizolopha moorei*, and *Protarea vetusta.* Ten feet below the base of the Silurian section occurs limestone corresponding to the comparatively unfossiliferous limestone at the base of the quarry a mile northeast of Osgood, and to the top of the exposures at the north end of Versailles.

About 5 miles northwest of Zenas, and 6 miles west of the Honey creek locality, near the mouth of Painter creek, a mile and a half southeast of Westport, the top of the Ordovician, exposed in a vertical section 15 feet thick, contains the following fossils, which have been listed also from other localities farther east: *Dalmanella* small species with very convex brachial valves, *Hebertella* near *occidentalis*, *Hebertella sinuata*, Madison bed form of *Platystrophia*, *Platystrophia acutilirita*, *Leptaena rhomboidalis*, *Strophomena sulcata*, *Strophomena vetusta*, large form of *Plectambonites* strongly deflexed anteriorly, *Rhynchotrema capax*, *Trematis millepunctata*, *Protarea vetusta*, *Streptelasma rusticum*, and *Streptelasma divaricans*. *Dinorthis subquadrata*, not noted so far at this horizon, occurs also.

From Versailles the top of the Madison bed is exposed almost continuously along Big Graham creek as far as Benville. At New Marion the fossiliferous clayey beds overlying more solid limestones produce a section easily recognized as equivalent lithologically and faunally to that at the top of the Madison bed at Versailles. Four miles north of Benville, a mile and a half south of Nebraska, the banks of Otter creek expose a considerable section of Richmond rocks, about 60 feet thick, all of which is placed in the Madison bed, being regarded as a nearly complete section of the Madison bed at this locality. The fossils include the Madison bed form of *Platystrophia*, *Hebertella* near *sinuata*, and *Streptelasma divaricans*. At some horizons bryozoans are rather common, and their study may accomplish much in the future in confirming or combating the views here expressed, since the bryozoans are better horizon markers as a rule in the Cincinnati formations than the brachiopoda. In fact, the observations here recorded are direct evidence of the limited value of brachiopoda as horizon markers since most of the species here listed for the first time from the Madison bed have long been known from lower horizons in the Richmond.

Unconformity between Madison and Niagaran beds comparatively small.—The thickness of the Madison bed varies in an irregular manner in Indiana and western Kentucky, but in general there is a decrease in thickness on passing from Madison southward toward central Kentucky. In the opposite

direction, on passing from Kentucky toward Indiana, there is an increase of thickness and the observations so far made indicate that this increase continues northward from Madison toward the areas in the central part of Ripley and Jennings counties, in which the Clinton is absent. The two or three feet of fossiliferous strata at the top of the Madison bed at Madison appear to be the attenuated representatives of the much thicker fossiliferous beds at the top of the Madison bed in the central part of Ripley and Jennings counties. The Silurian, therefore, instead of resting upon lower beds of Richmond age in the region in which the Clinton is absent, actually rests on beds representing the latest deposits of Madison age so far studied. The small degree of unconformity between the top of the Ordovician and the base of the Silurian in the areas of Indiana, Ohio, and northern Kentucky, so far under investigation, is a most striking feature, considering the great lapse of time intervening between their disposition, as indicated by the great difference of their faunas.

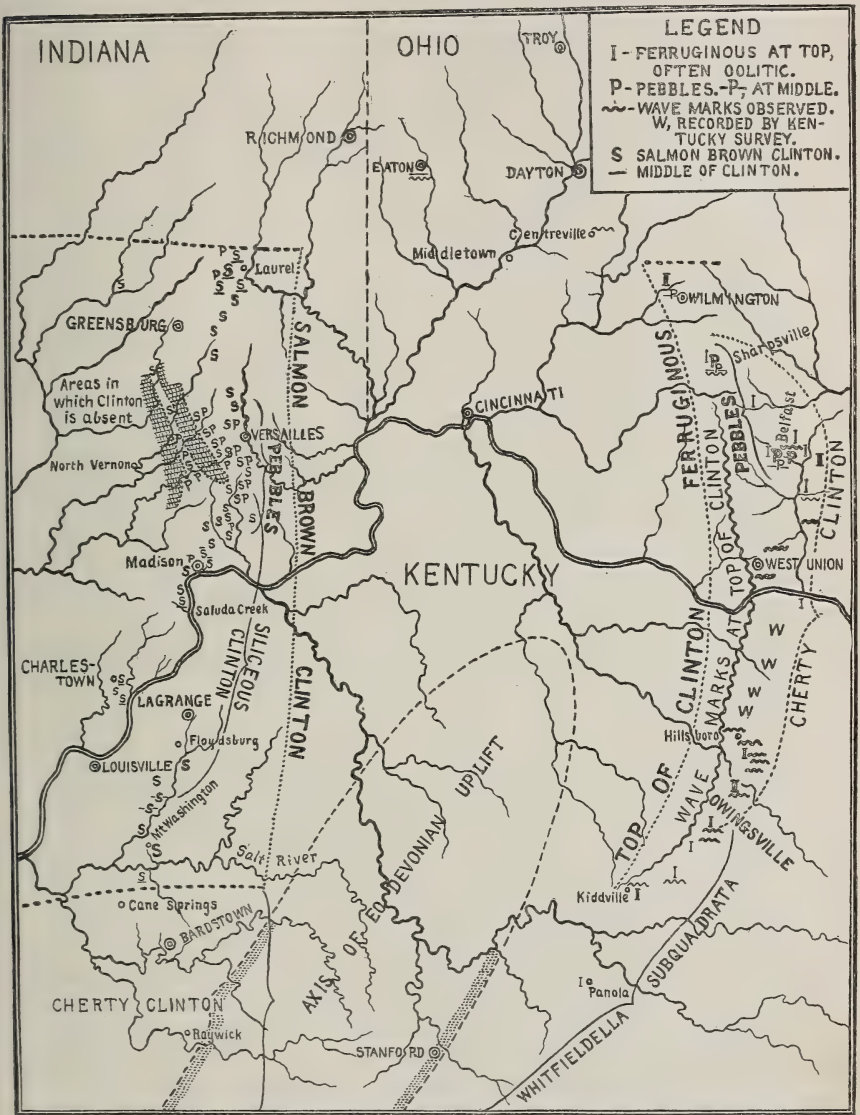
The *Lophospira hammelli–Holopea hubbardi* fauna may be traced from the southern margin of Ripley county to Floydsburg, in Kentucky, about 13 miles southeast of Charlestown landing. The fauna appears to be a depauperate one, a number of genera being represented by species of comparatively small size.

Parallelism of certain features shown by Clinton on opposite sides of the geanticline.—Along the same line of exposures, between the northwestern corner of Switzerland county and Lagrange, in Kentucky, the Clinton is usually quite thin, has a light red or pink instead of a salmon-brown color, and lithologically appears to be a dense siliceous limestone instead of a detrital limestone. Salmon-brown detrital phases are seen along this line but are less common. The area in which the siliceous phases of the Clinton are common is indicated on the accompanying map. Farther south, toward Mount Washington and for a short distance south of Salt river, in Kentucky, the salmon-brown, detrital phases of the Clinton are seen again. Northward, the salmon-brown phases of the Clinton extend as far as Laurel, Indiana.

The salmon-brown color of the Clinton in Indiana and western Kentucky appears to be due to the presence in very small quantity of some iron compound, sufficient to stain the calcite, but not visible to the eye, even under a microscope, as a substance distinct from the calcite. In Ohio and Kentucky, east of the Cincinnati geanticline, ferruginous layers occur at the top of the Clinton at many localities * within an area which

*Ohio Geol. Surv., iii, p. 442, 1878. Ohio Geol. Surv., Rept. for 1870, pp. 268, 269. Kentucky Geol. Surv., Rept. on Bath county, by W. N. Linney, p. 18, 1886. On the Clinton oolitic iron ores, this Journal, xli, 28, 1891.

has approximately the same northward and southward extension as the salmon-brown Clinton west of the geanticline. The



Map showing similar distribution of conglomeratic, ferruginous, and siliceous phases of the Clinton on opposite sides of the Cincinnati geanticline.

extent of this area is indicated on this plate. At the Rose Run Mining Company quarries, 4 miles east of Owingsville, the

ferruginous layers have a thickness of 3 feet and are sent to the iron furnaces along the Ohio river. The rock was originally a detrital limestone, more or less oolitic, but has in the course of time been replaced in part by a red iron ore which often preserves the structure of the fragments and of the more complete specimens of fossils, indicating the source of the material to which the rock owes its original composition. The rock was formerly quarried for use in smelters also at other localities in Kentucky and Ohio, but the development of iron industries elsewhere, in other states, on a much larger scale, has led to the abandonment of these workings in the Clinton of Kentucky and Ohio at all localities except at Owingsville.

Pebbles are found in the Clinton of Ohio at other localities* than the locality first described by Professor Orton. They are abundant at several horizons in the Clinton near Sharpsville. The area within which they are fairly common is indicated on the accompanying map. It is interesting to notice that this area is located directly east of the area in Indiana where pebbles are so common. At some localities in Ohio the pebbles are of much larger size than those usually found in Indiana; at one locality 2 miles east of Belfast, pebbles 4 to 8 inches in length are common, and quite a number attain a length of 12 inches. They are always strongly rounded.

Wave-marks are characteristic of the top of the Clinton over a wide area in Kentucky and Ohio. The extent of this territory is indicated on the accompanying map; it is almost coincident with the extent of the area containing ferruginous deposits.

In case the Cincinnati geanticline was already sufficiently developed in Clinton times to form a barrier in southern Ohio, Indiana, and adjacent Kentucky, the opposition of conglomeratic and salmon-brown deposits of Clinton age, west of the geanticline, to conglomeratic, ferruginous, and wave-marked deposits east of the geanticline may have little connection. In case this barrier did not exist, the observations so far made are in favor of a gradual diminution in thickness of the Clinton across the northern part of the field. They do not exclude the possibility of the former presence of the Clinton, thinning westward, even across the northern extremity of Kentucky. In this case the same cause may have been operative in both territories, east and west of the geanticline. The evidence of wave and current action is much stronger in the area east of the geanticline than westward. It is impossible to determine from the evidence at hand whether the few feet of Clinton strata west of the geanticline, in the region nearest the areas from which the Clinton is absent, are to be regarded as equiva-

*Journ. Geol., iii, pp. 16–30.

lent to the upper part of the Clinton east of the geanticline or as practically equivalent to the entire eastern section. So far no great difference has been noticed in the faunas in the upper and lower parts of the Clinton, east of the geanticline.

Additional notes on the development of the Cincinnati geanticline.—The pre-Meso-Devonic origin of the Cincinnati geanticline is shown best in Kentucky and Tennessee. Along the crest of the geanticline Devonian rocks rest on Ordovician formations, but both east and west of the crest the Devonian rests on successively younger beds of the Niagaran. The thinning out of the Louisville bed diagonally up the western flank of the geanticline from at least 60 feet at Louisville to nothing at Greensburg, and a similar thinning from the eastern parts of Bartholomew and Shelby counties eastward toward Greensburg, suggest similar conditions farther northward, in Indiana. At Greensburg,* according to Mr. J. A. Price, the sandy limestone of the Devonian rests directly upon the upper layers of the Laurel bed, even the Waldron bed being absent. The pre-Meso-Devonic age of the geanticline is indicated also in southern Ohio,† where, according to Professor Orton, neo-Devonian black slates or shales rest in succession on Niagaran, Cayugan, and Meso-Devonic limestones on proceeding from Highland county across Ross toward Franklin and Delaware counties. The presence of unconformable contacts between the Niagaran and Devonian in northern Indiana, at Delphi, Georgetown, and Kentland,‡ has been shown by Dr. E. M. Kindle. The evidence at hand, however, does not demonstrate the presence of the Indiana branch of the geanticline in pre-Devonic times.

The most interesting contribution of Dr. Kindle to the pre-Meso-Devonic geology of northern Indiana is the demonstration of the presence of strongly quaquaversal dips affecting Silurian rocks previous to the deposition of the Devonian. At some localities these dips suggested the presence of small domes. Quaquaversal dips, although usually of a much less pronounced character, are shown by Silurian strata also in central and southern Kentucky, and along the western flank of the geanticline in Tennessee. In fact, all the evidence so far accumulated indicates that while the Cincinnati geanticline in general shows a very simple structure, locally it may show strongly quaquaversal dips connected with subsidiary folds whose axes may be very divergent from the main axis of the geanticline. Owing to the low inclination of the rocks over the greater part of the area, these subsidiary folds attract much more attention than they would in a more highly inclined series of rocks.

* Indiana Geol. Surv., 24th Rept., pp. 87–90.
† Ohio Geol. Surv., Rept. for 1870, pp. 285–287.
‡ This Journal, vol. xv, p. 459, 1903.

Quaquaversal dips may have existed even before the deposition of the Niagaran. The variations in thickness of the Clinton in some parts of Kentucky and Tennessee are of an irregular character and can not be correlated in such a manner as to demonstrate the presence of the Cincinnati geanticline in pre-Niagaran times. The presence of wave-marks and pebbles in the Clinton of Ohio, Indiana, and northern Kentucky may have been connected with the existence in early Silurian times of very low irregular elevations of land of comparatively small extent in a very shallow expanse of sea covering wider areas. Similar wave-marks and pebbles are found at various elevations in the Richmond group in southwestern Ohio,* northern Kentucky, and southeastern Indiana.

The formation of the Cincinnati geanticline probably began with a general elevation of the sea bottom over wide areas, producing shallow waters. The irregular distribution at different levels of wave-marks and pebbles in rocks of Richmond age show that during late Ordovician times the waters were locally sufficiently shallow to bring the sea bottom within the range of action of waves, some parts being probably exposed to the air, at least at low tide. Along the western ranges of the Alleghanies there may have been a wide expanse of dry land, since the Richmond is absent eastward. Later there was a depression of the area eastward permitting the deposition there of the neo-Niagaran, but no deposits of this kind are known in the region of the Cincinnati geanticline, although their existence has been inferred in eastern and northern Ohio, below the cover of later rocks, from the records of drillers.

During early Niagaran times the depression appears to have progressed sufficiently to permit of the deposit over wide areas of the Clinton. There is no evidence, however, that the Clinton ever reached the western half of Indiana and the adjacent part of Kentucky. During the Clinton irregular shallow water conditions prevailed in certain areas. The Osgood clays may formerly have extended across the region of the present Cincinnati geanticline. The moderate quaquaversal dips of the earlier part of the Niagaran were followed in some areas by the stronger quaquaversal dips of the later Silurian. Just when the changes in level involved resulted in the production of the initial stages of the axis of the present Cincinnati geanticline is unknown, but it probably preceded Devonian times since in the Meso-Devonian the Cincinnati geanticline had attained considerable development.

While the origin of the Cincinnati geanticline in pre-Meso-Devonic times can be demonstrated, it owes its present proportions chiefly to later orogenic processes. In Ohio, the labors of Professor Orton have demonstrated to what a remarkable extent the present development of the geanticline was depend-

* Journ. Geol., 1895, pp. 6, 7, 9-11.

ent upon post-Meso-Devonic folding. His sections from Bryan to Sandusky,* and from Bryan to Bucyrus show this clearly, and similar sections collated from his notes on the well records of more southern areas indicate to what a large extent the geanticline owes its importance to post-Meso-Devonic folding. The strong eastward dip of the neo-Devonic black shales and of the Waverly indicate that a great part of this folding was probably of post-Mississippian age. Similar facts are observed also along the Ohio river, west of the crest of the geanticline, near Louisville,† where it is evident that the rapid westward dips affecting the neo-Devonic black shale and the Mississippian strata are largely instrumental in giving prominence to the geanticline. Similar facts are observed also in Kentucky and Tennessee. The elevation of the Cincinnati geanticline was therefore a process, probably more or less interrupted, but continuing through long geological ages, the greater part of the development of this fold having taken place in post-Devonian, and probably in post-Mississippian times.

Approximate relationship of Clinton and Osgood Faunas of Indiana to the lower Niagaran Faunas of New York.

The Osgood bed introduces the typical Niagaran fauna. Here are found the first species of *Gomphocystites*, *Holocystites*, *Stephanocrinus*, *Pisocrinus*, and *Lecanocrinus;* here are found the first specimens of *Pentamerus oblongus*, *Rhynchotreta cuneata americana*, typical *Camarotoechia neglecta*, *C. indianensis*, *Atrypa reticularis*, *Spirifer radiatus*, *Sp. eudora*, *Sp. niagarensis*, *Cyrtea exporrecta*, *C. myrtea*, *Nucleospira pisiformis*, *Whitfieldella cylindrica*, *Atrypa calvani*, *Orthoceras amycus*, *O. medullare*, and *Dalmanites limulurus*.

The Clinton of Ohio, Indiana, and Kentucky contains a fauna so different from that of New York and other eastern localities that the existence of some sort of a barrier between these two areas has been suggested. The attempt formerly to identify western Clinton species by means of the plates in the second volume on the paleontology of New York has resulted in various errors not yet corrected. It is certain that the species identified as *Strophonella patenta* from the Clinton of Ohio is distinct from the type species described from New York and the name *Strophonella daytonensis* is here suggested for the same. The identification of *Phacops trisulcatus* rests upon very unsatisfactory grounds. Such names as *Cornulites distans*, *Orthoceras clavatum*, *O. virgulatum*, *Conularia niagarensis*, and *Murchisonia subulata*, can have little value

* Ohio Geol. Surv., vi, 1888, pp. 48, 134, 183, 305. Am. Geol. 1891, pp. 105–108.

† Indiana Geol. Surv., 25th Rept., map, p. 349; Silver Creek Hydraulic limestone, by C. E. Siebenthal; also 26th Rept., 1903, maps, pp. 235, 261; Geological section across southern Indiana, by J. F. Newsom.

until much better representatives of the type species are secured. *Sphaerexochus pisum* is a species of *Deiphon* and is closely related to *D. forbesi.* Representatives of genera more abundantly represented in the Ordovician occur in the Clinton, such as *Platystrophia daytonensis*, *Pl. reversata*, *Hebertella fausta*, *H. daytonensis*, *Cyclonema daytonensis.* A form of *Plectambonites* allied to *Pl. sericea* is the only species passing from the Ordovician into the Clinton with little change; the more distinct form, *Pl. transversalis*, however, is much more common. The identification of the lowest Silurian bed in the area of the Cincinnati geanticline as Clinton does not rest so much upon the identity of faunas at the two localities as upon the presence of a few species which are identical, a few which are closely allied, the general absence of species which may be regarded as most typical of the Rochester shale of New York, and a general facies which suggests that the western fauna represents a somewhat similar stage in development.

In New York, some of the species, which in the area of the Cincinnati geanticline are not found beneath the Osgood bed, occur in the lenses at the top of the Clinton; some of them occur even in the upper beds of the Clinton. As far as may be determined from the evidence at hand, the Osgood bed contains a part of the fauna of the lenses at the top of the Clinton and of the lower half of the Rochester shales in New York, a part of this fauna beginning at the top of the Clinton in that state; while the Clinton of Ohio, Indiana, and Kentucky appears to have attained the stage of development equivalent to that of the Clinton of New York, below the lenses, but does not contain such species as *Pentamerus oblongus*, *Atrypa reticularis*, *Spirifer radiatus*, *Sp. niagarensis*, which in the west begin their existence in the Osgood bed. The faunal elements of the Clinton in the two areas are different and a more exact comparison is at present impossible.

Lists of Niagaran Fossils.

The best lists of the fossils of the various subdivisions of the Cincinnatian strata in Ohio, Indiana, and adjacent Kentucky are those published by Mr. J. M. Nickles in the Journal of the Cincinnati Society of Natural History, volume xx, No. 2, 1902.

A list of the fossils identified from the Clinton of Indiana was published in "Silurian and Devonian limestones of Tennessee and Kentucky," a Bulletin of the Geological Society of America, in 1901, on pages 438–441.

Osgood Fossils.

In the following list the names of the localities Osgood, New Marion, and Big Creek are indicated by the letters O, N, and B following immediately after the name of the species. Unless

otherwise recorded, the crinoids and cystids are from Big Creek:

Receptaculites ———, B.
Ceramopora imbricata. O,N,B.
Mesotrypa milleri, O.
Idiotrypa parasitica, O.
Callopora elegantula, O.
Pachydictya crassa, O.
Duncanella borealis, O,N.
Favosites forbesi, O,B.
Favosites cristatus, B.
Striatopora flexuosa, O.
Striatopora sessile on crinoid stems, O.
Thecia major, O.
Plasmopora ———, O.
Allocystites hammelli, Rikers Ridge.
Caryocrinus ellipticus, O.
Caryocrinus indianensis.
Caryocrinus hammelli.
Caryocrinus ornatus.
Gomphocystites indianensis.
Holocystites abnormis, Madison ?
adipatus.
affinis.
amplus, Big Creek ?
asper.
brauni.
benedicti.
bacculus.
canneus.
colletti.
commodus.
cylindricus.
dyeri, Osgood.
elegans.
faberi.
globosus.
gorbyi.
gyrinus.
hammelli.
indianensis.
madisonensis.
ornatissimus.
ornatus.
ovatus, Madison ?
papulosus.
parvulus.
parvus.
perlongus, O.
plenus.
rotundus, O.
scitulus.
spangleri.
spaeroidalis.
splendens.
subglobosus, Big Creek ?
subovatus.
subrotundus, O.
tumidus.
turbinatus, O.
ventricosus, O.
wetherbyi, O.
wykoffi.
Pisocrinus gemmiformis, O,N,B, Nebraska.
Stephanocrinus cornetti, B, Rikers Ridge.
deformis.
elongatus, O,B.
hammelli, O.
obpyramidalis.
osgoodensis, O.
quinquepartitus.
Orthis flabellites, O,N,B, Nebraska.
Platystrophia biforata, Nebraska.
Dalmanella elegantula, O,N.
Rhipidomella hybrida, O,N, Nebraska.
Leptaena rhomboidalis. N,B.
Plectambonites transversalis, O,N,B, Nebraska.
Rhynchotreta cuneata-americana, O.
Camarotoechia neglecta, N,B.
Camarotoechia indianensis, O.
Atrypa reticularis, O,N,B.
Spirifer radiatus, N,B.
Spirifer eudora, N.
Spirifer niagarensis, N,B.
Cyrtia exporrecta, N,B.
Cyrtia myrtea (meta !), N.
Nucleospira pisiformis, N.
Whitfieldella cylindrica, N.
Whitfieldella quadrangularis, B.
Atrypa calvani, B.
Diaphorostoma niagarense, O,N,B.
Orthoceras simulator, B.
Orthoceras amycus, O,B.
Orthoceras medullare, B.
Calymmene nasuta, O,B.
Dalmanites limulurus, O.
Illaenus ———, O,B.

In Ohio Pentamerus oblongus occurs in the Dayton limestone, equivalent to the base of the Osgood bed.

Laurel Fossils.

Unless otherwise stated, the fossils are from St. Paul.

Amplexus	cinctutus, Miller.
Favosites	spongilla, Rominger.
Streptelasma	spongiaxis, Rominger.
Striatopora	gorbyi, Miller.

Plasmopora	follis, Milne-Edwards.
Plasmopora	scita ? Milne-Edwards.
Aethocystites	sculptus, Miller.
Allocrinus	benedicti, Miller.
Calceocrinus	indianensis, Miller.
Callicrinus	beachleri, Wachsmuth + Springer.
Caryocrinus	ellipticus, Miller + Gurley.
Cyclicocrinus	canaliculatus, Miller.
Cyclicocrinus ?	indianensis, Miller + Gurley.
Cyphocrinus	gorbyi, Miller.
Emperocrinus	indianensis, Miller + Gurley.
Gazacrinus	inornatus, Miller.
Holocystites	pustulosus, Miller : a few miles from Waldron, Indiana, some distance below the range of Waldron beds.
Hyptiocrinus	typus, Wachsmuth + Springer.
Idiocrinus	elongatus, Wachsmuth + Springer.
Idiocrinus	ventricosus, Wachsmuth + Springer.
Indianocrinus	punctatus, Miller + Gurley.
Macrostylocrinus	indianensis, Miller + Gurley.
Mariacrinus	aureatus, Miller.
Mariacrinus	granulosus, Miller.
Melocrinus	equalis, Miller.
Melocrinus	oblongus, Wachsmuth + Springer.
Melocrinus	parvus, Wachsmuth + Springer.
Pisocrinus	baccula, Miller + Gurley.
Pisocrinus	globosus, Ringueberg.
Saccocrinus	benedicti, Miller.
Saccocrinus	howardi, Miller.
Saccocrinus	umbrosus, Miller + Gurley.
Stribalocystites	gorbyi, Miller.
Stribalocystites	tumidus, Miller.
Stribalocystites	spheroidalis, Miller + Gurley.
Zophocrinus	howardi, Miller.
Spirifer	radiatus, Sowerby. From Madison.
Cyrtoceras	howardi, Miller.
Cyrtoceras	indianense, Miller.
Orthoceras	annulatum,
Orthoceras	imbricatum,
Orthoceras	subcancellatum,
Cyrtoceras	elrodi, White.
Lichas	byrnesanus, Miller + Gurley. From neighborhood of Madison.
Lichas	hanoverensis. Miller + Gurley. From Hanover.

The fauna of the Waldron bed was described by Hall in the eleventh annual report of the Indiana Geological Survey, this being a republication of various papers in the Transactions of the Albany Institute and the New York State Museum Reports.

The brachiopod and gasteropod fauna of the Louisville bed was described by Henry Nettelroth in Kentucky Fossil Shells of the Silurian and Devonian Rocks, 1889, a publication of the Kentucky Geological Survey. The corals of the Louisville bed were figured by W. J. Davis, in Kentucky Fossil Corals of the Silurian and Devonian Rocks, 1885. In these publications all fossils cited from Silurian rocks, with the possible exception of *Zaphrentis patula*, *Z. socialis*, and *Z. patens*, come from the Louisville bed.

Dayton, Ohio.

Art. XXXVII.—*A Crystallographic Study of Millerite*; by Charles Palache and H. O. Wood.

The crystallographic character of millerite was first defined by Miller in 1835 in a paper* interesting historically as containing the first presentation of his index system of notation. He determined the forms o, (0001), b, $(10\bar{1}0)$, k, $(21\bar{3}0)$, e, $(01\bar{1}2)$, r, $(10\bar{1}1)$, r_1, $(01\bar{1}1)$ and v, $(50\bar{5}2)$ on crystals without natural terminations, but which had been broken across. And on a single terminated crystal with dull faces, he found the form t, $(03\bar{3}1)$ by contact measurement. The angle $o \wedge r = 20° \ 50'$ was the average of several readings, and led to the axial ratio $a : c = 1 : 0{\cdot}3295$ which is at present accepted. In the lack of details as to faces and measurements, we are forced to conclude that he, at that time, considered five kinds of cleavage present, parallel to o, e, r, r_1, and v. In his Mineralogy† the matter is presented somewhat differently. The prism a, $(11\bar{2}0)$ is added, and instead of v, $(50\bar{5}2)$, is given e_1, $(10\bar{1}2)$, without explanation. He also states that possibly the appearance of cleavage on both positive and negative rhombohedrons, r and r_1 and e and e_1, is due to concealed twinning on the vertical axis. The occurrence of the rhombohedron v, $(50\bar{5}2)$, is therefore left in doubt, and cleavage parallel to the base and to the two rhombohedrons r and e is indicated.

In 1892, Laspeyres‡ described beyrichite and paramorphs of millerite after beyrichite. He concludes that all millerite is derived from beyrichite, and that for the crystals of both minerals examined, the crystallographic characters are identical. The forms observed were b, $(10\bar{1}0)$, a, $(11\bar{2}0)$, i, $(41\bar{5}0)$, r, $(10\bar{1}1)$ and e, $(01\bar{1}2)$; the two last both as cleavages and as dull terminal faces, and each in apparently positive and negative positions through twinning about the vertical axis. The axial ratio $a : c = 1 : 0{\cdot}3277$ was derived from measurement of the cleavage rhombohedron.

The form i, $(41\bar{5}0)$, is based on poor measurements, the average differing by more than a degree from the calculated value, and therefore is to be regarded as very doubtful.

In 1893, the same author in a paper§ on the various nickel deposits of the Rhine, describes various occurrences of millerite. On specimens from two localities, terminated but not measurable crystals were observed, on which c, (0001) and r, $(10\bar{1}1)$ were present together with the ordinary prism forms.

The list of forms known on millerite up to the present time

* Phil. Mag., vi, 104, 1835.

† Phillips Mineralogy, 163, 1852.

‡ Zeitschr. f. Kryst., xx, 535, 1892.

§ Das Vorkommen und die Verbreitung des Nickels im Rheinischen Schiefergebirge. Verh. Nat.-hist. Ver. Rheinl., 1, 142, 1893.

reads then as follows: *b*, $(10\bar{1}0)$, *a*, $(11\bar{2}0)$, *k*, $(21\bar{3}0)$, *c*, (0001), *e*, $(01\bar{1}2)$, *r*, $(10\bar{1}1)$, and doubtful *i*, $(41\bar{5}0)$, *v*, $(50\bar{5}2)$ and *t*, $(03\bar{3}1)$. Cleavage parallel to *r* and *e* is established.

In the Mineral Cabinet of Harvard University is a suite of specimens derived from the collection of Prof. J. D. Whitney, illustrating the occurrence of millerite, and its associated minerals, at the old Nickel Mine at Orford, Province of Quebec. The beauty, perfection and unusual size of these crystals of millerite led to their study, and examination of the literature revealed the fact that no detailed description of this occurrence existed. Such a description is here presented, since the study of this material has added largely to our knowledge of the crystallography of millerite.

The nickel deposit occurs on the east side of Brompton Lake in Orford Township, Province of Quebec. It consists, as may be gathered from scattered notes in the Canadian Survey Reports, of a large vein chiefly composed of granular white calcite which traverses serpentine. Mingled with the calcite and especially abundant near the vein walls are considerable masses of a bright green chrome-garnet in granular aggregates, and of a light colored diopside, both granular and in long stout crystals. Millerite in grains and prisms is scattered irregularly through the vein matter. The deposit has long been known, and it seems to have been worked for a short time in the seventies, but was abandoned soon, the nickel content of the vein material, less than one per cent, having been too small to pay for extracting.

The specimens in hand consist chiefly of chrome-garnet, partly in granular masses, partly in aggregates of minute individual crystals held together by a cement of calcite, the removal of which with acid causes the mass to crumble. In the latter case, and indeed wherever the garnet is in contact with the calcite, it is in sharp crystals, with the dodecahedron as the dominant form. On a few crystals the dodecahedron edges were truncated by planes, which on measurement proved to be those of two hexoctahedrons, (358) and (459), the latter new to garnet. The faces were extremely narrow and the reflections poor, hence the considerable variations in the position of the faces.

Symbol.		Observed angles (av.).		No. of faces.	Calculated angles.	
Miller.	G_1.	ϕ	ρ		ϕ	ρ
(358)	$\frac{3}{8}\ \frac{5}{8}$	32° 12′	35° 37′	6	30° 58′	36° 05′
(385)	$\frac{3}{5}\ \frac{8}{5}$	21° 00′	60° 08′	5	20° 33′	59° 40′
(583)	$\frac{5}{3}\ \frac{8}{3}$	31° 21′	71° 42′	5	32° 00′	72° 21′
(459)	$\frac{4}{9}\ \frac{5}{9}$	39° 16′	35° 26′	6	38° 39′	35° 26′
(495)	$\frac{4}{5}\ \frac{9}{5}$	23° 36′	62° 43′	5	23° 58′	63° 05′
(594)	$\frac{5}{4}\ \frac{9}{4}$	28° 46′	68° 17′	5	29° 03′	68° 46′

The garnet is green in color, varying from a yellowish tone in massive specimens to a deep emerald-green in the sparkling transparent crystals.

The following analysis by T. Sterry Hunt is taken from Dawson, Geology of Canada, p. 497.

	I.	II.
SiO_2	36·65	
Al_2O_3	17·50	
Cr_2O_3	6·20	6·93
FeO	4·97	4·80
CaO	33·20	33·29
MgO	0·81	
Volatile	0·30	
Total	99·63	

The analysis shows that the garnet is ouvarovite, but with a very small proportion of chromium.

Specks of chromite are embedded in the garnet, in places quite abundantly.

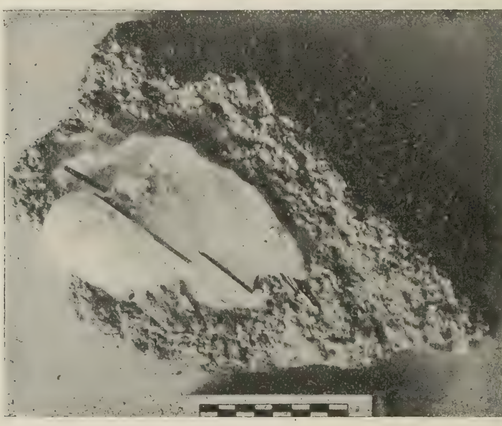
The pyroxene is yellow-gray or pale green, and is either in isolated crystals embedded in calcite, in granular masses consisting almost wholly of this mineral, or in minute crystals implanted on the surface of garnet aggregates. The crystals are prismatic and are often large, up to six or more inches in length. The pinacoids *a*, (100) and *b*, (010) are dominant, and narrow faces of the prisms *m*, (110) and *i*, (130) are always present. These forms always have smooth and brilliant faces; the terminating planes, on the contrary, are always dull and measurements could be obtained only with great difficulty. The forms *p*, ($\bar{1}01$) and *u*, (111) are always present and occasionally minute faces of *c*, (001), *s*, ($\bar{1}11$), and several other pyramids not corresponding to established pyroxene forms were noticed. Twins on the common pyroxene law, (100) the twinning plane, are common. No analysis of this material could be discovered.

The calcite vein-filling is snow-white and very coarsely granular, individual cleavage rhombs up to three inches across being at hand. It is characterized by an extreme development of pressure-twinning parallel to *e*, ($01\bar{1}2$), so that a parting parallel to the negative rhombohedron with smooth reflecting surfaces scarcely inferior to those of the cleavage, is often obtained. The occurrence of this twinning-parting in the calcite is especially noteworthy, since this identical structure is also developed in the millerite, as will be shown presently.

Millerite occurs scattered through the massive garnet, more abundantly at the boundary between garnet or pyroxene and calcite, and finally wholly embedded in calcite. The aggre-

gates of garnet, pyroxene, calcite and millerite are such that no sequence of formation can be recognized, all appearing rather to have crystallized together. When in the massive garnet the millerite is in grains of small size. On contact surfaces as developed by removal of calcite with acid, the millerite is either in short stout prisms loosely implanted on the garnet and projecting into the calcite with developed terminal planes; or it is in long and relatively slender striated prisms, which lie parallel to the garnet surface and adhere to it closely, being bent, twisted and contorted in extraordinary fashion as though, after formation, the crystals had been pressed down

1



to fit all the irregularities of the uneven underlying surface. Their appearance is unique; and no explanation of their probable mode of formation has occurred to us. So soon as the millerite passes from the immediate contact zone, and is embedded in calcite, the crystals are free from these extreme dislocations; the long prisms are sometimes warped and knicked by pressure-twinning, but entirely lose the crushed appearance as described above. Crystals may be seen crushed and twisted where they lie prone, but which pass into the calcite and become immediately relatively straight and plane-surfaced. The millerite crystals in the calcite reach dimensions quite unusual for this mineral. Prisms two millimeters in diameter and four centimeters long are present among our specimens. They are said to reach a length of eight centimeters or more (three inches). These prisms are generally sharply trigonal in outline, the three faces bright and polished

and the angles rounded and striated. No terminated crystals of this type were found, all showing terminal planes of cleavage only. A striking and hitherto unknown character of the mineral was first seen and interpreted on one of the triangular cleavage fragments shown in fig. 2. This crystal consists of three segments, the upper and lower ones parallel, the intermediate portion in twin position to the other two, a face of the form *e*, $(01\bar{1}2)$, being the twinning plane. $10\bar{1}1 \wedge \underline{10\bar{1}0}$ (twin), measured 21° 23′½, calculated 21° 25′. The form of the twin suggested that it might be due to the presence of a gliding plane and produced by pressure; and experiment soon showed this to be the case. A crystal held firmly and subjected to shearing stress can be offset readily. The same

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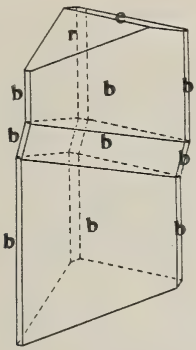

result may be obtained by placing the crystal on a yielding support, and pressing upon it transversely with a knife-edge, in which case a fine lamella is thrown into twin position. The gliding takes place with equal ease, of course, parallel to each of the three rhombohedron planes. With very slender crystals it is difficult to produce the twinning, the pressure breaking the brittle substance to pieces, and this probably accounts for the failure to recognize this remarkable property of millerite hitherto. Careful tests on millerite crystals from a number of localities were uniformly successful, and showed it to be a general property of the mineral. In view of the ease with which this gliding twinning can be obtained, and of the striking effect produced, it seems that millerite should take equal rank with calcite as an illustration of this interesting phenomenon.

Highly perfect cleavage is present parallel to the unit rhombohedron, *r*, $(10\bar{1}1)$, and also to the negative rhombohe-

dron, *e*, $(01\bar{1}2)$, the latter identical with the gliding plane. No difference in the quality of the two cleavages can be detected, and planes of both are generally produced when a crystal is broken. No indication of a cleavage parallel to a prism, such as Laspeyres found in millerite derived from beyrichite, was observed.

The Orford millerite is characterized by brilliant metallic luster, and a pale brass-yellow color which is quite constant on all planes and surfaces of the mineral. Laspeyres' conclusion mentioned above, that all millerite is derived from beyrichite, a conclusion based largely on an observed color change, finds absolutely no support in this occurrence.

No analysis of the millerite was made. Careful qualitative tests for copper and cobalt gave only negative results, and it is probably very nearly pure nickel sulphide.

Crystallography.

A number of crystals showing natural terminal planes were obtained from several of the specimens by removal of calcite with hydrochloric acid. In the majority of cases, the crystals were attached to the matrix by an end and thus showed but a single termination; two or three crystals of poor quality were found which were attached by prism faces and thus showed both terminations. These crystals were in all cases small, from 2 to 5^{mm} in length, and from $0{\cdot}1^{mm}$ to 1^{mm} in diameter. In habit they vary from slender prisms to short stubby crystals of diameter equal to or greater than their length.

In all thirty-two crystals were measured. Of these twenty-eight were measured completely in the two-circle goniometer. Four were measured for special angles.

From the data obtained in measurement, the following forms were established, those marked with a star being new: *b*, $(10\bar{1}0)$, *a*, $(11\bar{2}0)$, *k*, $(21\bar{3}0)$, *d*, $(72\bar{9}0^*)$, *r*, $(10\bar{1}1)$, *v*, $(50\bar{5}2)$, *p*, $(02\bar{2}1^*)$, *s*, $(21\bar{3}1^*)$ and *u*, $(\bar{4}\bar{1}53^*)$. Doubtful values for the following forms were found. These need confirmation for their establishment. *i*, $(41\bar{5}0)$, *f*, $(9{\cdot}4{\cdot}\bar{13}{\cdot}0^*)$, *g*, $(31{\cdot}13{\cdot}\bar{44}{\cdot}0^*)$, *t*, $(03\bar{3}1)$, *h*, $(30\bar{3}1^*)$, *x*, $(40\bar{4}1^*)$, *j*, $(50\bar{5}1^*)$, *l*, $(09\bar{9}1^*)$, *m*, $(0{\cdot}18{\cdot}\bar{18}{\cdot}1^*)$, *n*, $(52\bar{7}6^*)$, *o*, $(7{\cdot}4{\cdot}\bar{11}{\cdot}9^*)$, *q*, $(51\bar{7}4^*)$, and *w*, $(42\bar{6}5^*)$. The only forms satisfactorily established which we did not find on the Orford mineral are the base *c*, (0001), which was observed by both Miller and Laspeyres, and the rhombohedron *e*, $(01\bar{1}2)$ observed by the latter.

Measurements were obtained from the dominant rhombohedrons from which a satisfactory axial ratio could be calculated.

For r, $(10\bar{1}1)$

10	readings,	very good	signals,	average	value of	$\rho=20° \, 43'{\cdot}4$
11	"	good	"	"	"	$\rho=20° \, 42'{\cdot}8$
4	"	fair	"	"	"	$\rho=20° \, 43'{\cdot}5$
12	"	poor	"	"	"	$\rho=20° \, 41'{\cdot}5$
37	"	all sorts	"	"	"	$\rho=20° \, 42'{\cdot}6$

For p, $(02\bar{2}1)$

3	readings,	very good	signals,	average	value of	$\rho=37° \, 07' \tfrac{1}{3}$
6	"	good	"	"	"	$\rho=37° \, 03' \tfrac{1}{2}$
6	"	fair	"	"	"	$\rho=37° \, 07' \tfrac{1}{2}$
6	"	poor	"	"	"	$\rho=37° \, 17' \tfrac{1}{3}$
12	"	very poor	"	"	"	$\rho=37° \, 12' \tfrac{1}{3}$
Mean of 24	"	selected	"	"	"	$\rho=37° \, 09'{\cdot}0$
Mean of 15	"	best	"	"	"	$\rho=37° \, 05'{\cdot}8$

(The word selected as used above means that, using the averages found in the columns above, the whole number of readings whose signals were very good, good and fair was summed with half the number of readings whose signals were poor and very poor, and the general average then taken, weighted in this manner to avoid giving undue influence to the relatively large number of inferior readings.)

Using the formula $pp_0\sqrt{3}=\tan \rho$ and the above values, we obtain,

$$p=1, \quad \rho=20° \, 42'{\cdot}6, \quad p_0=0{\cdot}21828$$
$$p=2, \quad \rho=37° \, 05'{\cdot}8, \quad p_0=0{\cdot}21830.$$

Taking the value of $p_0=0{\cdot}2183$ we have from the relation

$$c=\tfrac{3}{2}\,p_0, \quad a:c=1:0{\cdot}3274.$$

This value of p_0, which is based on a large number of measurements, is probably to be given preference over Miller's value; it is exceedingly near the value of p_0 for beyrichite found by Laspeyres.

Found, millerite	$p_0=0{\cdot}2183$
Miller "	$p_0=0{\cdot}2197$
Laspeyres, beyrichite	$p_0=0{\cdot}2185$

Accordingly a table of angles based on the new value is presented to replace that given in Goldschmidt, Winkeltabellen, p. 242. It contains the new forms, and in a supplement those doubtful ones not yet fully established. This constitutes Table I.

TABLE I—MILLERITE.

Hexagonal. Rhombohedral-hemihedral.

$c=0·32745$ $lgc=9·51514$ $lga_0=0·72341$ $lgp_0=9·33905$ $a_0=5·2895$ $p_0=0·2183$. (G_2)

Number.	Letter.	Symb. G_2.	Bravais.	ϕ.	ρ.	ξ_0.	η_0.	ξ.	η.	x Prisms $x:y$.	y.	d $=tg\,\rho$.
1	*c*	0	0001	0° 00′	0° 00′	0° 00′	0° 00′	0° 00′	0° 00′	0	0	0
2	*b*	∞	$10\bar{1}0$	30° 00′·	90° 00′	90° 00′	90° 00′	30° 00′	60° 00′	0·5773	∞	∞
3	*a*	$\infty 0$	$11\bar{2}0$	0° 00′	90° 00′	0° 00′	90° 00′	0° 00′	90° 00′	0	∞	∞
4	*k*	4∞	$21\bar{3}0$	10° 53′·	90° 00′	90° 00′	90° 00′	10° 53′·	79° 06′·	0·1924	∞	∞
5	*d*	$\frac{11}{5}\infty$	$72\bar{9}0$	17° 47′	90° 00′	90° 00′	90° 00′	17° 47′	72° 13′	0·3207	∞	∞
6	*r*	1	$10\bar{1}1$	30° 00′	20° 42′·	10° 42′·	18° 08′	10° 11′	17° 50′	0·1890·	0·3274·	0·3781
7	*v*	$\frac{5}{2}$	$50\bar{5}2$	30° 00′	43° 23′·	25° 18′	39° 18′·	20° 05′·	36° 30′·	0·4726	0·8186.	0·9452·
8	*p*	-2	$02\bar{2}1$	30° 00′	37° 06′	20° 42′·	33° 13′	17° 33′	31° 29′·	0·3781	0·6544	0·7562
9	*e*	$-\frac{1}{2}$	$01\bar{1}2$	30° 00′	10° 42′·	5° 24′	9° 18′	5° 20′	9° 15′·	0·0945	0·1634	0·1890·
10	*s*	41	$21\bar{3}1$	10° 53′·	45° 00′·	10° 42′·	44° 29′.	7° 41′	43° 59′	0·1890·	0·9823·	1·0003·
11	*u*	-21	$\bar{4}\bar{1}53$	19° 06′·	38° 00′·	10° 42′·	28° 37′.	9° 25′	28° 12′·	0·1890·	0·5457·	0·5775·
?	*i*	2∞	$41\bar{5}0$	19° 06′·	90° 00′	90° 00′	90° 00′	19° 06′·	70° 53′·	0·3464	∞	∞
?	*f*	$\frac{17}{5}\infty$	$9·4·\bar{1}\bar{3}·0$	12° 31′	90° 00′	90° 00′	90° 00′	12° 31′	77° 28′·	0·2220	∞	∞
?	*g*	$\frac{19}{6}\infty$	$31·13·\bar{4}\bar{4}·0$	13° 17′	90° 00′	90° 00′	90° 00′	13° 17′	76° 42′.	0·2361	∞	∞
?	*h*	3	$30\bar{3}1$	30° 00′	48° 36′·	29° 33′·	44° 29′·	22° 01′·	40° 31′	0·5671·	0·9823·	1·1343
?	*t*	-3	$03\bar{3}1$	30° 00′	48° 36′·	29° 33′·	44° 29′·	22° 01′·	40° 31′	0·5671·	0·9823·	1·1343
?	*x*	4	$40\bar{4}1$	30° 00′	56° 31′·	37° 06′	52° 38′·	24° 39′	46° 15′	0·7562	1·3098	1·5724
?	*j*	5	$50\bar{5}1$	30° 00′	62° 07′·	43° 23′·	58° 35′	26° 14′	49° 57′	0·9452	1·6372	1·8905
?	*l*	-9	$09\bar{9}1$	30° 00′	73° 37′·	59° 33′·	71° 15′·	28° 40′	56° 11′	1·7014·	2·9470	3·4030
?	*m*	$-18·18$	$0·18·\bar{1}\bar{8}·1$	30° 00′	81° 38′·	73° 37′·	80° 22′	29° 41′·	59° 02′	3·4030	5·8940	6·8060
?	*n*	$\frac{3}{2}\ \frac{1}{2}$	$5·2·\bar{7}·6$	13° 59′	21° 29′	5° 24′	20° 54′·	5° 03′	20° 44′·	0·0945	0·3820	0·3935·
?	*o*	$\frac{5}{3}\ \frac{1}{3}$	$7·4·\bar{1}\bar{1}·9$	8° 57′	22° 03′·	3° 36′·	21° 48′·	3° 21′·	21° 46′·	0·0630	0·4002	0·4051·
?	*q*	$-\frac{8}{4}\ \frac{5}{4}$	$\bar{6}\bar{1}74$	22° 24′·	31° 47′·	13° 18′	29° 49′	11° 35′	29° 09′	0·2363	0·5730	0·6198
?	*w*	$\frac{8}{5}\ \frac{2}{5}$	$42\bar{6}5$	10° 53′·	21° 48′·	4° 19′·	21° 27′	4° 01′·	21° 23′·	0·0756	0·3929	0·4001·

Table II shows the character of the combinations observed on the measured crystals, the numbers under each letter indicating the number of faces of that form found on the given crystal.

TABLE II.

	b	*a*	*k*	*d*	*r*	*p*	*v*	*s*	*u*
A	6	1	.	.	2	.	.	.	.
1	6	.	1	1	1	1	.	.	.
2	6	2	3	2	2	1	.	.	6
3	6	2	1	2	3	3	.	.	.
4	6	2	.	2	3	.	.	.	6
5	3	1	.	.	3	1	.	.	1
6	4	.	.	.	3	3	.	.	.
7	6	6	2	.	3	.	.	.	3
8	6	.	.	.	3	3	.	.	.
9	6	4	.	4	3	3	.	.	1

	b	*a*	*k*	*d*	*r*	*p*	*v*	*s*	*u*
12	6	4	.	1	3	.	.	.	.
13	6	2	.	.	.	.	.	.	.
14	4	.	.	.	.	3	.	.	1
15	*x*	.	.	.	*x*	*x*	.	.	*x*
16	4	.	.	.	3	3	2	.	.
17	3	.	.	.	3	3	.	.	.
18	3	.	.	.	3	3	1	.	.
19	1	.	.	1	3	1	.	5	1
20	1	.	.	.	3	3	2	.	.
21	1	.	.	.	3	3	2	.	.
22	.	.	.	.	3	.	.	3	.
23	2	.	.	.	1	.	1	.	.
24	6	.	.	.	1	3	.	.	.
25	2	.	.	.	2	1*	.	.	.
26	3	.	.	.	1	.	.	.	2
27	3	.	.	.	1*	.	.	.	4
30	2	.	.	.	3	.	.	.	.
31	.	.	.	.	x*	.	.	.	.

(The star indicates that the crystal was doubly terminated, but the faces on one end only are given.)

The forms may be characterized as follows:

Prisms.

The prisms usually show a triangular cross-section with rounded corners, but sometimes the cross-section is nearly circular. This is due in part to the development of three or four prisms, partly or completely, and in part to the oscillatory combination of these prisms. The prism zone is badly striated in its length from this cause and in measurement yields signals every few degrees.

b, $(10\bar{1}0)$. Twenty-four out of the twenty-eight crystals which were measured systematically showed faces of the first order prisms, and eleven of these showed all its faces. It is easily the dominant form on the mineral, and it is the least striated of any prism. In most cases it was developed trigonally.

a, $(11\bar{2}0)$. The second order prism was also undoubtedly present on nine crystals, although but one had every face. Its faces when large were considerably striated.

k, $(21\bar{3}0)$. This known prism was found developed incompletely, but none the less surely on four crystals. Its faces were narrow and poorly characterized.

d, $(72\bar{9}0)$. This new prism was found developed incompletely on seven crystals, and the data establishing it are given in full in the following table:

Crystal.	Signal.	Reading. ϕ	
1	very poor	16° 48′	
2	very poor	17° 30′	
2	very poor	17° 33′	
3	poor	17° 58′	
3	poor	17° 59′	
4	good	17° 47′	
4	very good	17° 51′	
9	fair	17° 11′	
9	good	17° 42′	
9	poor	18° 25′	
9	fair	18° 26′	
12	very poor	17° 45′	
19	fair	16° 48′	
Average	fair to poor	17° 47′	average.
Calculated		17° 47′	

The calculated value of ϕ for this form is curiously in exact agreement with the mean of the measurements. So, although

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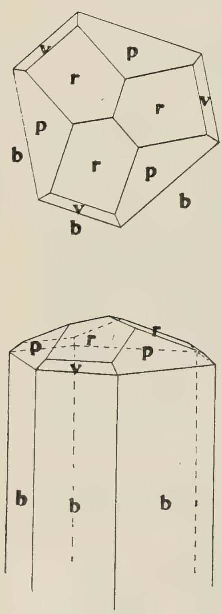

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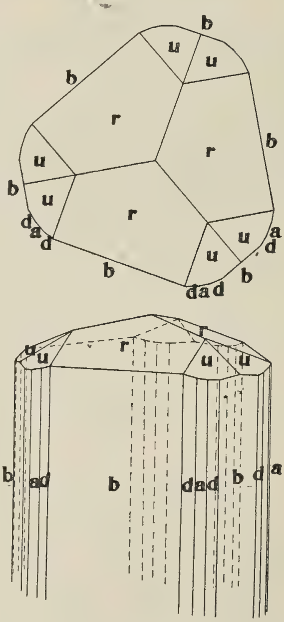

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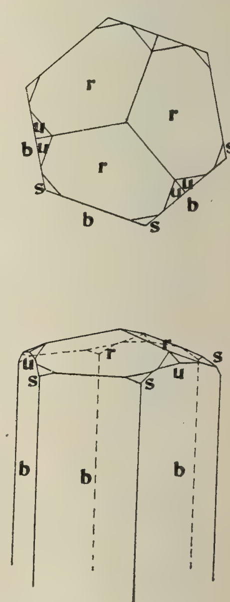


this precise agreement is of course mere chance, it is near enough to establish the form and there are faces enough, well distributed among the crystals, to confirm it. Its faces are narrow and quite indistinguishable from the oscillation planes with which it is associated.

Rhombohedrons.

These are the chief terminating faces whether they occur as cleavage or as crystal planes. The faces, when crystal planes, are not very bright, although the markings and roughnesses which make them dull are never well characterized.

r, $(10\bar{1}1)$. The unit rhombohedron was found on all but two of the measured crystals. In a very few instances it was certainly cleavage; and in a few cases it was impossible to say whether cleavage or natural growth had produced the facet. It was developed in relatively large and perfect facets, constituting the dominant terminating form. While not always of good reflecting quality, the faces were usually definite and exhibited no definite markings.

p, $(02\bar{2}1)$. Next to *r* the new rhombohedron *p* is best developed as a termination. It is not found as cleavage. It occurs in rather large faces of dull reflecting power for the most part. It is missing from nine crystals only out of the twenty-eight measured, occurring, therefore, with less frequency than *r*. No definite markings were seen on its faces. The observations on which it is based are stated in summary form on p. 349.

v, $(50\bar{5}2)$. This rhombohedron, noted by Miller in his first paper, but omitted from his Mineralogy, occurs on five of the crystals, three of them, singly terminated, showing two faces each. The measurements on which the form is based follow.

Crystal.	Signal.	Readings.		
		ϕ	ϕ_1*	ρ
16	good	$\bar{2}9°\ 39'$	$29°\ 39'$	$44°\ 03'$
16	good	$\bar{1}49°\ 41'$	$29°\ 41'$	$43°\ 57'$
18	very good	$\bar{1}49°\ 19'$	$29°\ 19'$	$43°\ 23'$
20	poor	$\bar{3}0°\ 42'$	$30°\ 42'$	$43°\ 33'$
20	good	$\bar{1}50°\ 07'$	$30°\ 07'$	$43°\ 25'$
21	fair	$\bar{2}9°\ 52'$	$29°\ 52'$	$43°\ 24'$
21	good	$\bar{1}50°\ 10'$	$30°\ 10'$	$43°\ 25'$
24	fair	$89°\ 31'$	$29°\ 31'$	$43°\ 51'$
Average	very good to fair		$29°\ 53'$	$43°\ 39'$
Calculated			$30°\ 00'$	$43°\ 23'$

Scalenohedrons.

These forms are entirely new to millerite. They are present on the Orford mineral as small but distinct facets on over half the crystals measured. The faces are fairly bright, yielding good images, and for the most part they are not pitted or striated.

s, $(21\bar{3}1)$. This scalenohedron occurs on two singly terminated crystals, in one case five of its faces being present. The measurements which establish it are given below.

* ϕ_1 is the value of ϕ referred to the first sextant on the right, that is, the difference between ϕ and the nearest multiple of 60°.

Crystal.	Signal.	Readings. ϕ	ϕ_1	ρ
19	fair	$\bar{1}1°$ 13′	11° 13′	44° 59′
19	very poor	$\bar{4}9°$ 03′	10° 57′	44° 59′
19	good	$\bar{1}30°$ 55′	10° 55′	45° 01′
19	good	$\bar{1}69°$ 06′	10° 54′	45° 01′
19	very poor	109° 10′	10° 50′	45° 01′
22	fair	$\bar{4}9°$ 24′	10° 36′	44° 55′
22	fair	$\bar{1}31°$ 16′	11° 16′	45° 00′
22	poor	$\bar{1}69°$ 29′	10° 31′	45° 00′
	Mean of 8		10° 54′	44° 59′·5
	Calculated		10° 53′·	45° 00′·

The form is seen to be well established by these results.

u, ($\bar{4}\bar{1}53$). This scalenohedron occurs on ten crystals, in two cases all its faces being present. The faces, however, are not very bright. They are rough and pitted for the most part and the images are only fair. The data follow.

This scalenohedron and the uncertain ones, *n*, *o*, *q* and *w*, lie in the zone with the rhombohedrons *r* and *p*, and their faces generally appear as striations or roundings of the edges between *r* and *p*, or as shown in figure 4, without *p*.

Crystal.	Signal.	Readings. ϕ	ϕ_1	ρ
2	extremely poor	20° 02′	20° 02′	30° 07′
2	fair	40° 23′	19° 37′	30° 33′
2	good	139° 21′	19° 21′	30° 03′
2	good	160° 57′	19° 03′	30° 01′
2	extremely poor	$\bar{1}01°$ 08′	18° 52′	30° 01′
2	very poor	$\bar{7}8°$ 14′	18° 14′	30° 01′
4	very poor	40° 33′	19° 27′	30° 11′
4	extremely poor	139° 42′	19° 42′	30° 11′
4	extremely poor	160° 26′	19° 34′	30° 11′
4	extremely poor	$\bar{1}00°$ 00′	20° 00′	30° 11′
4	extremely poor	$\bar{8}0°$ 05′	20° 05′	30° 11′
4	extremely poor	20° 37′	20° 37′	30° 11′
5	very poor	141° 36′	21° 36′	30° 40′
7	extremely poor	138° 41′	18° 41′	30° 40′
7	extremely poor	161° 25′	18° 35′	30° 40′
7	extremely poor	$\bar{7}9°$ 32′	19° 32′	30° 40′
9	poor	$\bar{9}9°$ 52′	20° 08′	30° 42′
19	very poor	159° 51′	20° 09′	30° 45′
26	poor	41° 20′	18° 40′	30° 00′
26	very poor	18° 51′	18° 51′	29° 49′
27	poor	41° 07′	18° 53′	29° 42′
27	poor	100° 12′	19° 48′	29° 42′
27	very poor	161° 48′	18° 12′	29° 42′
27	very poor	138° 38′	18° 38′	29° 42′
	Mean of all (24)		19° 24′·	30° 04′
	Mean of best		19° 05′	30° 07′
	Calculated		19° 06′	30° 00′·

Doubtful Forms.

The following forms, for one reason or another, given in detail under each form, are presented as possibly present on the species, but not as established beyond cavil.

i, $(41\bar{5}0)$. This form was reported by Laspeyres, but not very well established by his measurements. We obtained poor measurements partly confirming it, but the form is still in doubt, neither his measurements nor ours being good enough to certify it. Our measurements follow.

Crystal.	Signal.	Reading. ϕ
2	extremely poor	18° 52′
2	extremely poor	18° 58′
2	poor	19° 01′
Average	very poor	18° 57′
Calculated		19° 06′·4

The agreement of our measurements with the calculations is better than that of Laspeyres's measurements, but the faces noted were all on one crystal, and two of them were very doubtful.

f, $(9{\cdot}4{\cdot}\bar{1}\bar{3}{\cdot}0)$. This prism is new and the measurements on which it is based follow.

Crystal.	Signal.	Reading. ϕ
7	fair	12° 26′
12	poor	12° 29′
14	very good	12° 29′
Average	fair to good	12° 28′
Calculated		12° 31′·2.

The agreement is close enough to establish the form, but the faces are few in number, though well distributed. The signals, however, are good, and in the case of crystal 14, at least, the reading corresponds to a definite face of good quality which can be seen in the goniometer. In this respect the face differs from most of the oscillation planes and, moreover, it is placed very close to its computed position. Therefore the form is regarded as probable, but confirmation is necessary.

g, $(31{\cdot}13{\cdot}\bar{4}\bar{4}{\cdot}0)$. This prism, so far as our measurements go, is better established than the form *i*, and so is given, but it has complex indices and altogether is a doubtful form.

Crystal.	Signal.	Readings. ϕ
2	extremely poor	13° 11′
8	extremely poor	13° 22′
14	good	13° 19′
Average	poor	13° 17′·3.
Calculated		13° 17′

Besides the signals reflected from faces of these forms which are more or less well established, there were read, in the prism zone, signals reflected from faces in thirty-two positions (reduced to the positive sextant) which corresponded more or less well to prisms of complex indices. For the most part only one face of each of these forms was seen, and the signals were generally of very poor quality. These facts together with the complexity of the indices deduced, and the certainty of the occurrence of oscillation-vicinals whose signals correspond to no prism however complex, render the establishment of any of them very doubtful. Therefore all are rejected and none of the data is published.

Doubtful Rhombohedrons.

t, (03$\bar{3}$1). This rhombohedron was reported by Miller on the strength of a contact measurement on a rough terminated crystal. We can not confirm the form, but one face on one crystal was found approximating to its position.

Crystal.	Signal.	Readings. ϕ	ρ
24	very poor	30° 00′	48° 56′
Calculated		30° 00′	48° 36′

h, (30$\bar{3}$1). This rhombohedron is new and very doubtful, relying for its establishment on two measurements on two different crystals.

Crystal.	Signal.	Readings. ϕ	ρ
23	very poor	30° 00′	48° 42′
24	fair	150° 00′	48° 10′
Mean	poor	30° 00′	48° 26′
Calculated		30°	48° 36′

The form is therefore certainly indicated, but by no means established.

x, (40$\bar{4}$1). This form also is new and rests on a single measurement whose signal was of fair quality. The measured value for ρ was 56° 34′; the calculated value of ρ is = 56° 31′49″; apparently the form only lacks the finding of more faces to establish it.

j, (50$\bar{5}$1). One face only supports this form.

Crystal.	Signal.	Readings. ϕ	ρ
23	poor	29° 46′	62° 26′
Calculated		30° 00′	62° 07′

l, (09$\bar{9}$1). Only one face of this form was found. This gave a fair signal showing a definite face.

Crystal.	Signal.	Readings. ϕ	ρ
25	fair	29° 25′	73° 05′
Calculated		30° 00′	73° 37′

m, $(0\cdot18\cdot\bar{18}\cdot1)$. Only one face of this form was found which yielded two signals of fair quality.

Crystal.	Signal.	Readings. ϕ	ρ
24	fair	30° 00′	82° 32′
24		30° 00′	80° 20′
Calculated		30° 00′	81° 38′

No stress is laid on the probability of the occurrence of *l* and *m*. The faces were plainly visible in both cases.

Doubtful Scalenohedrons.

n, $(52\bar{7}6)$. This form was found on three crystals, in one case four of its faces being present. The data follow:

Crystal.	Signal.	Readings. ϕ	ϕ_1	ρ
5	good	104° 52′	15° 08′	21° 18′
5	poor	133° 21′	13° 21′	21° 18′
8	poor	$\bar{1}33°$ 14′	13° 14′	21° 22′
8		$\bar{4}6°$ 39′	13° 21′	21° 22′
8		73° 01′	13° 01′	21° 22′
8	very poor	$\bar{1}66°$ 45′	13° 15′	21° 22′
14	poor	$\bar{1}67°$ 14′	12° 46′	21° 26′
Mean	poor	-------	13° 26′·5	21° 21′
Calculated		-------	13° 54′	21° 29′

Although we have left the form in doubt it is clear that it is more than indicated. The agreement of measurements with calculations is only fair, but there are many faces well distributed.

o, $(7\cdot4\cdot\bar{11}\cdot9)$. This form was found on three crystals, in one case four faces being present. The data are given in full:

Crystal.	Signal.	Readings. ϕ	ϕ_1	ρ
5	poor	$\bar{8}°$ 52′	8° 52′	22° 03′
5	very poor	$\bar{5}0°$ 58′	9° 02′	22° 00′
8	extremely poor	$\bar{7}°$ 30′	7° 30′	21° 22′
18	poor	$\bar{9}°$ 51′	9° 51′	21° 19′
18	extremely poor	$\bar{1}71°$ 40′	8° 20′	21° 51′
18		$\bar{1}28°$ 24′	8° 24′	21° 36′
18	poor	$\bar{4}9°$ 46′	10° 14′	21° 09′
Mean	very poor	-------	8° 53′	21° 37′
Calculated		-------	8° 57′	22° 03′

This form, therefore, is not to be rejected without consideration although the data cannot be said to establish it.

q, $(\bar{6}\bar{1}74)$. This form rests on two readings made on a single crystal. This crystal was the richest in forms of any measured. The agreement is not very bad. The form is at least indicated.

Crystal.	Signal.	Readings. ϕ	ϕ_1	ρ
2	poor	$\bar{8}3°\ 05'$	$23°\ 05'$	$32°\ 00'$
2	very poor	$\bar{9}7°\ 33'$	$22°\ 27'$	$32°\ 00'$
Mean	poor	....	$22°\ 46'$	$32°\ 00'$
Calculated		....	$22°\ 24'$	$31°\ 47'$

w, $(42\bar{6}5)$. Only one reading supports this form. It in consequence is very doubtful.

Crystal.	Signal.	Readings. ϕ	ϕ_1	ρ
5	fair	$70°\ 26'$	$10°\ 26'$	$21°\ 47'$
Calculated		....	$10°\ 53'$	$21°\ 48'$

Résume.

The Orford millerite has yielded a number of terminated, measureable crystals from which the new axial ratio $a : c = 1 : 0{\cdot}2183$ is calculated. In addition to the forms previously known, one new prism, two rhombohedrons and two scalenohedrons are definitely established and a number of uncertain forms observed but not established.

The presence of a gliding plane parallel to the negative rhombohedron, along which pressure twins of great perfection can be easily obtained, is also determined.

Millerite has been thought to be hemimorphic like the nearly related cadmium sulphide, greenockite, and has been so classified by Groth. The sharply defined trigonal character of many of the prisms of Orford millerite seem to give some basis for this assumption; and doubly terminated crystals were therefore eagerly sought for in the hope that the question might be settled by definite observations. A few crystals doubly terminated were found but they were poor crystals and so far as measurements could be made upon them showed no unlikeness between the two ends. Our evidence on this matter is therefore not conclusive.

On the surface of a single hand specimen of very rich green chrome garnet which was originally covered with a thin layer of calcite, there appeared on the removal of the latter with acid a number of tiny clusters of crystals of a gray to white metallic mineral which seem to be rammelsbergite, an arsenide of nickel. The crystals are minute and invariably so deeply striated that no satisfactory measurements could be obtained. Still inasmuch as this mineral has never been found before in crystals that permitted of measurement except in one zone, a number of the crystals were studied carefully and a provisional axial ratio was calculated for the species. It was found to be like the other

members of the marcasite group in habit and the flat dome which was found on all measured crystals was taken by analogy with arsenopyrite as the brachydome (014). The prism zone was so deeply striated that no reliance could be placed on the readings made from it; but an orthodome was found on nearly all the crystals very faintly developed but which gave fairly uniform readings for ρ. This was taken as (102), a choice that gave the simplest indices for the prism forms and a ratio most nearly like that of the other members of the group, although differing widely from any of them. The observations follow:

Rammelsbergite?.

$$\left.\begin{array}{lll} 0\frac{1}{4} \text{ av. of } 7, & \phi = \ \ 0°\ 00', & \rho = 16°\ 06' \\ \frac{1}{2}0 \text{ av. of } 4, & \phi = 90°\ 00', & \rho = 45°\ 15' \end{array}\right\} \begin{array}{l} p_o = 2{\cdot}0176 \\ q_o = 1{\cdot}1545 \end{array}$$

$$a : b : c = 0{\cdot}57222 : 1 : 1{\cdot}1545$$

Form.		Calculated.		Measured.		No. of
G.	Miller	ϕ	ρ	ϕ	ρ	observations.
0∞	010	00° 00′	90° 00′	00° 00′	90° 00′	6
∞	110	60° 13′	90° 00′	60° 44′	90° 00′	3
$\infty 2$	120	74° 02′	90° 00′	74° 26′	90° 00′	4
2∞	210	41° 09′	90° 00′	42° 30′	90° 00′	2
$0\frac{1}{4}$	014	00° 00′	16° 06′	00° 00′	16° 06′	7
$0\frac{1}{3}$	013	00° 00′	21° 03′	00° 00′	20° 30′	2
$0\frac{1}{2}$	012	00° 00′	29° 59′	00° 00′	29° 45′	1
02	021	00° 00′	66° 35′	00° 00′	66° 50′	1
$\frac{1}{2}0$	102	90° 00′	45° 15′	90° 00′	45° 15′	4

The amount of the mineral present on our specimens was so small that sufficient for analysis could not be secured. Its doubtful determination as rammelsbergite is based on blowpipe reactions for arsenic and nickel obtained on minute crystals. No test for sulphur could be obtained. It is hoped that more and better material may ultimately be obtained which will enable the character of this mineral to be definitely established.

EXPLANATION OF THE FIGURES.

Fig. 1 shows a photograph of a specimen from which calcite has been partly removed by solution in hydrochloric acid. Several large straight prisms of the millerite may be seen still partly embedded in the calcite. On the surface of the pyroxene matrix may be seen several smaller broken and twisted millerite crystals.

Fig. 2 shows a twin crystal produced by pressure, twinned parallel to the rhombohedron e, $(01\bar{1}2)$. The upper termination is formed by single planes of the two cleavages, parallel to r and e; the lower termination is by a single plane of the r cleavage.

Fig. 3 shows in plan and perspective the commonest type of crystal found. The proportions of the rhombohedrons may vary but some or all of the faces of the three are generally found.

Fig. 4 and Fig. 5 show the mode in which the scalenohedrons occur in combination. Of these forms u is much the more frequent, s having been observed on but two crystals.

Harvard Mineralogical Laboratory,
June 1904.

Art. XXXVIII.—*Unconformity of the Cretaceous on Older Rocks in Central New Mexico;* by Charles R. Keyes.

In New Mexico Cretaceous sedimentation is enormously developed. The total thickness of the strata referable to this age cannot be less than 7000 feet.

In eastern New Mexico and Texas the sequence of the Cretaceous formations is quite complete. Both the Lower Cretaceous and the Upper Cretaceous are well represented. Below are the "Red Beds," probably composed partly of Triassic sandstones and shales and partly of Carboniferous layers of similar lithologic characters. These attain a thickness of 2000 feet and upwards. Then below all these are the great Carboniferous limestones, which are about 2000 feet thick and which form the backslopes of most of the block mountains of the Basin region. The generalized geological section for New Mexico may be tabulated as follows:

Ages.	Systems.	Thickness.	Formations.	Rocks.
Cenozoic	Quaternary	200		Gravels
	Tertiary	200	Galisteo	Sandstones
		800	Puerco	Clays
Mesozoic	Cretaceous	2000	Laramie	Sandstones
		1500	Montana	Shales
		800	Colorado	Shales
		400	Dakota	Sandstones
		800	Comanche	Sandstones
	Triassic	1000	Cimarron	Shales
Paleozoic	Carboniferous	1000	Bernalillo	Shales
		300	Madera	Limestones
		300	Sandia	Limestones
		200	Lake Valley	Limestones
	Devonian	200	Chloride	Limestones
	Ordovician	400	Pinos Altos	Limestones
	Cambrian	300	Tonto	Sandstones
Azoic	Algonkian	300	Chuar	Shales
		1000	Grand Canyon	Sandstones
		500	Vishnu	Quartzites
	Archean	2000		Schists

The relationships of the Cretaceous system to the other formations, as displayed in central New Mexico, have long been a puzzle. Throughout the region the Red Beds constitute a conspicuous and important formation. Owing, how-

ever, to the peculiar position they occupy when well exposed on the lower backslopes of the block mountains, with the Cretaceous coming in immediately, the exact disposition of the two great formations is seldom clearly discernible. Then, too, at the bases of mountains vast plains stretch away, which are deeply covered by gravels, sands and clays washed down from the higher elevations, and which cover effectually all traces of the indurated rocks beneath. While these underlying rocks usually are more or less highly inclined, they have been completely bevelled off to a surface that is as even and level as the plains themselves.

That the Cretaceous rocks in central New Mexico rest unconformably on the older formations has been for some time surmised. The difficulty has been to obtain indisputable evidence in support of this hypothesis. This proof has lately been secured; and the facts are of exceptional interest.

1

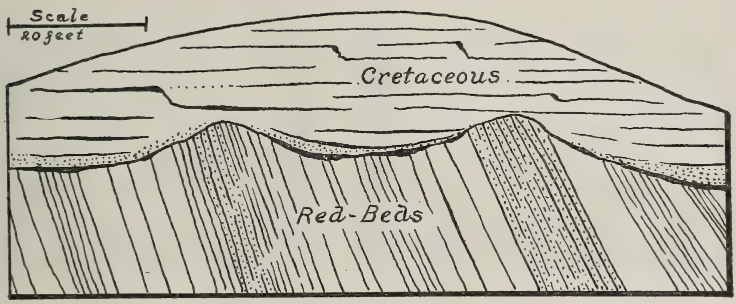


FIG. 1. Cretaceous and Red Beds at Tejon, New Mexico.

In a number of instances the Cretaceous sandstones have been found to repose apparently in perfect conformity upon the Carboniferous limestones. There is no evidence whatever of the existence of the great thickness of Red Beds between sandstone and limestone. If the Red Beds ever existed there they were swept cleanly away from the surface of the limerock. But the bedding planes of the Carboniferous and Cretaceous formations were to all appearances parallel.

East of the Sandia Mountains the Cretaceous deposits extend almost uninterruptedly to the Texas line. At the north end of the range where the backslope of Carboniferous limestone begins to sink under the plains, a small stream has cut deeply through the Cretaceous sandstones into the Red Beds beneath. At this place the Red Beds are standing on end, while the yellow Cretaceous beds are lying very nearly horizontally. The relationships are best indicated by diagram (figure 1).

A still more instructive section is displayed in the canyons cutting the Chupadera Mesa, 50 miles east of Socorro. The surface rock of the great mesa is horizontally disposed Cretaceous sandstone, rather massively bedded and yellowish in color. The dissecting canyons are 300 to 400 feet deep. They disclose the blue Carboniferous limestones in many places. A number of enormous dikes of gray trachyte traverse the district where the limestones are displayed. Along these dikes are large deposits of iron ore. On either side of the dike the limestone is abruptly upturned, often nearly to a vertical attitude. The cross-section is shown in the subjoined cut (figure 2).

2

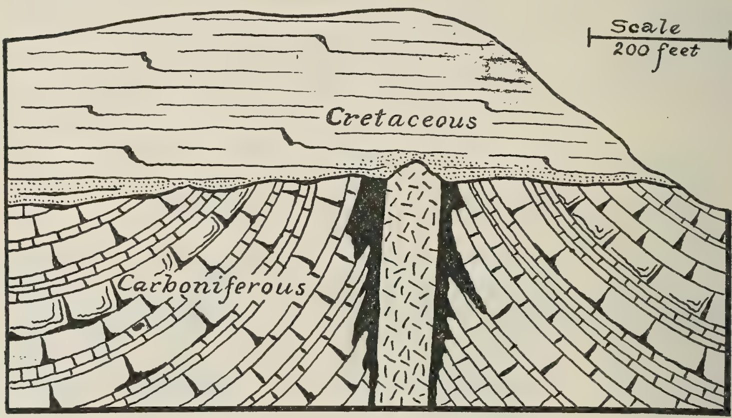


Fig. 2. Unconformity of Cretaceous on Carboniferous.

At this particular point the Cretaceous beds repose horizontally, while in a distance of a thousand feet the Carboniferous limestones change in dip from horizontal to vertical. The dike is 200 feet thick. The iron ore on either side is of varying thickness, and fills the jagged edges of the broken limestone.

With the recognition of an enormous erosion interval in central New Mexico prior to the deposition of the Cretaceous sandstones, the working out of the geology of the region is greatly simplified. Many hitherto inexplicable phenomena now find easy solution. The Cretaceous of the region is all Upper Cretaceous. Nowhere have the Lower Cretaceous beds been found.

The duration of the erosion interval was thus probably equivalent to the sedimentation period of the entire Lower Cretaceous of the Texas area.

New Mexico School of Mines, Socorro, August 30, 1904.

ART. XXXIX.—*A Peculiar Occurrence of Bitumen and Evidence as to its Origin;* by WM. CONGER MORGAN and MARION CLOVER TALLMON. (With Plates XVIII and XIX.)

Summary.

THE following is a description and an account of the examination of a fossil egg from Arizona. When discovered it was enclosed in a limestone matrix which has kept the specimen in a very fine state of preservation. Crystallized colemanite and a tarry material resembling natural asphalts are found within the eggshell. All the evidence which can be collected from the specimen indicates that the asphalt-like substance is part of the original contents of the egg which has become bitumized.

Introduction.

Very few instances of the occurrence of eggs in the fossil state have been recorded. The fossil eggs of New Zealand birds are only shells which have been preserved by reason of their thickness and strength. The Chelonian eggs of Tertiary age from Auvergne, France, are simply shells filled with hardened mud. An interesting fossil egg from the American Miocene has been described by Mr. Oliver C. Farrington,* and has been considered the egg of a duck.

The specimen described in this paper was brought to the attention of Professor John C. Merriam some months ago by Mr. G. A. Helmore of San Francisco. It had been in Mr. Helmore's possession for some years, and was obtained by him from a prospector who found it in a large pebble embedded in placer gravels on the Gila River in Arizona. Mr. Helmore, being unwilling to part with the specimen, has kindly loaned it to the University of California for study and description. To Professor Merriam the authors wish to acknowledge their indebtedness for valuable suggestions during the course of the work.

Occurrence.

Unfortunately, the information which we have concerning the occurrence of this specimen does not give us very definite evidence concerning its age. The encapsuled egg is said to have been a pebble in gravels some distance above the present level of the river. If, as has been supposed, the gravels are bench deposits, the egg is at least as old as the Quaternary. If they are of recent origin, we can still hardly suppose it younger than Quaternary, as it is only under the most extraordinary circumstance that deposits of recent origin can occur as hard pebbles in recent conglomerates.

* Field Columbian Museum, Pub. 35, vol. i, No. 5, Geological Series. A Fossil Egg from South Dakota.

Description.

The egg as found forms the center of a rounded mass of hard calcareous rock, which may be called the capsule or matrix. Its appearance is that of an ordinary irregularly-shaped river pebble, about $3\frac{1}{2} \times 4 \times 5$ inches in dimensions. It is well worn by the action of water, and shows striations in a plane parallel with the longer diameters, apparently due to differential weathering of the thin layers of the matrix. By a blow of a pick a piece was broken out of one side of the pebble, revealing a smooth inner core, from the appearance of which the finder had no hesitation in pronouncing it a fossil egg embedded in rock. When the specimen came into our possession, part of the surrounding matrix had been removed and the egg broken open. (Pl. XVIII, figs. 2 and 4.)

In order to expose fresh surfaces for observation the matrix was completely removed. It separated readily and exposed what appears externally to be a typical egg in all respects. (Pl. XVIII, fig. 1.) It is oval in shape, but little removed from an ellipsoid, however, and measures 62×40^{mm} ($2{\cdot}44 \times 1{\cdot}57$ inches). Its shape indicates very clearly that it belongs to the class of water-birds, and by comparison with the eggs of birds of the present time, it is found to correspond closely with the type of egg laid by the cormorant. The character of the shell is entirely unlike these rough chalk-coated eggs, however, but shows a finely pitted surface with some degree of polish such as is found in eggs of the duck family. The minutest markings of the shell are preserved in the matrix, moreover, and in this there is no evidence of any scratches such as usually occur in the chalky layer of cormorant's eggs. It is true that the shell proper lying underneath the outer chalky layer of a cormorant's egg shows a pitted surface much like that of the present fossil specimen. It seems improbable, however, that the chalky layer could have been washed off without injury being done to the egg, neither is it probable that it was firmly united with the matrix and pulled away in separating the egg-shell from the rock.

While the specimen most resembles in shape the type egg of the cormorant, it is also much like the egg of the larger grebes or herons, the American bittern or limpkin. Again, while the ratio of the short to the long diameter is somewhat less than that of the typical egg of the duck, its dimensions correspond almost exactly with measured eggs of many of the larger species of this family, thus showing that its divergence from the type is not greater than could be accounted for by individual variation.

In microscopic structure the same similarity is apparent. Under the lens the shell of a wild goose or of a duck's egg is

practically indistinguishable from the fossil shell, which shows distinctly the two characteristic layers, the outer one veined, the inner one prismatic. (Pl. XIX, figs. 2*a* and 2*b*.) The shell is light buff in tint, but any inference from its present to its original color would hardly be significant. It is probable that when this egg was deposited the region was not near to the sea. Under geographic conditions similar to those now obtaining, ducks would be more numerous than any of the other possible forms, and the probabilities, therefore, favor anatine origin of the egg.

Since it was not desirable to mutilate the specimen unnecessarily a quantitative analysis of the shell was not possible. Qualitative analyses of the shell of the fossil egg and the shell of a wild-goose's egg were made in parallel, on approximately equal amounts of material in equal volumes of solution with the same number of drops of the different reagents. With the exception of organic matter the fossil gave tests for every element found in the egg of the goose apparently to the same degree, the only difference noticeable being that the fossil contained a trifle more iron.

Taking into consideration the facts that the fossil eggshell is in chemical composition similar to, and in physical structure practically indistinguishable from, the shells of birds' eggs of the present time, the hypothesis that the material of the fossil eggshell as it exists to-day is the same as was present originally seems unquestionable. Moreover, the minute tracings of the shell are reproduced on the inner surface of the surrounding capsule. This fact makes it necessary to assume that the egg was encased very soon after it was deposited in the nest, and that subsequently it has been subjected to no conditions likely to modify its microscopic structure.

Contents.

By far the larger portion of the contents of the egg consists of beautifully crystalline colorless colemanite, showing the characteristic plates, striations, cleavage, hardness, extinctions and other physical properties. (Pl. XIX, fig. 1.) An analysis gives the following composition:

	Calculated.	Found.
CaO	27·21 per cent	27·07 per cent
B_2O_3	50·93 "	51·00 "
H_2O	21·85 "	22·01 "

While the colemanite in many places comes in direct contact with the shell of the egg, in other places it is separated from

it by a tarry material which, wherever it occurs, is invariably in contact with the shell. The main deposit of this tar is assumed to be on the lower side of the egg as it lay buried. (Pl. XIX, fig. 1, *t*.) The contacts between this deposit and the colemanite above it are smooth, gently rounding surfaces, without inclusions of either substance in the other. The second largest deposit of tar is almost diametrically opposite the one just mentioned, on what seems to have been the upper side of the eggshell. While the character of the tar is identical, the nature of the contact is entirely different. A little mass of tar of irregular shape is almost completely surrounded by the colemanite and hangs down from above like a pendant. (Pl. XIX, fig. 1, *t'*.) Other slight deposits of tar in various parts of the egg present only similar phenomena. No inclusions of the colemanite in the tar could be anywhere detected.

The surfaces bounding the cavity in the colemanite in which the tar is included are smooth and roughly spherical. Had the colemanite crystallized freely, we should expect the bounding surfaces to be right-lined and planar, conforming to the faces of the crystals, and not spherical as in the present instance. The shape of any deposit of material subsequently laid down must of necessity correspond to those surfaces on which it is deposited. Considering the inclusion of the tar in the mineral, the shape of the included mass and the nature of the contacts, there seems to be no doubt that the entrance of the colemanite took place after the tar had already accumulated inside the shell. Hence it was that the colemanite crystallized about the tar, the nature of the surfaces of contacts being determined by the tar and not by the crystallizing mineral.

Besides the deposits of tar inside the shell, there is a thin film of the same material between the shell and the matrix, adhering to both. On the inner surface of the matrix, a number of small black prominences are plainly in evidence (Pl. XIX, fig. 3), which, under the lens, seem to be minute deposits of the same tarry material. They readily disappear when the rock is washed off with chloroform, and, after thorough extraction, in place of the prominences little globular cavities or sacks are found. (Pl. XIX, figs. 3 and 4.) The diameters of these openings increase after penetrating beneath the surface of the matrix. Microscopically examined, the limestone about these cavities appears identical in character with that removed from their vicinity. The cavities are found to correspond with visible canals in the eggshell. The number of pits in a given piece of matrix corresponds with the number of visible passages in that part of the shell from which the matrix was removed, the relative distribution of each being about the same. A minute crack in the shell is also filled with tar and

a corresponding tarry ridge is noticeable in the matrix. Since the homogeneity of the matrix offers no evidence to indicate that the little cavities are the remains of passages to the exterior, subsequently filled with more recently deposited material, and since the juxtaposition of cavity in the matrix and canal in the eggshell offers evidence that the cavities were formed from within, there seems to be no reasonable hypothesis other than that the tar at present outside the shell and in the immediate layers of the matrix came from within and was forced outward from the center.

To offer a reasonable explanation of the formation of these pits is not an easy matter. Since they are intimately connected with the canals through the eggshell, and these canals as well as the pits are filled full with tar, it would seem as though some corroding action of the tar might be connected with their formation. Not the slightest acid reaction can be obtained from the tar in any way with litmus or phenolphthalein, however; hence the solution of the limestone would hardly seem to be due directly to the tar.

The ready solubility of calcium carbonate in water containing carbon dioxide naturally suggests itself. However, the formation of carbon dioxide or of organic acids from the original decomposition of the egg can hardly be supposed to have caused the action. It is questionable whether a limestone matrix could form about an egg before its contents had broken down to relatively very stable decomposition products. Moreover, if these pits had been present in the matrix when the colemanite came in, they would in all probability have been filled with this mineral. It is necessary to assume either that these pits did not exist when the colemanite came in, or that they were already filled with tar which prevented the mineral from filling them. Since the tar that fills them unquestionably came from inside the shell, the only force considered sufficient to make a viscous tar leave a large cavity to fill a small pit would be due to the crystallizing colemanite. As the crystals formed, the resulting pressure forced the tar through the larger canals in the eggshell. Through the fine-grained matrix it could not go because of its viscosity.

The fact that the tar filling these pits has an earthy appearance, like that produced in the "weathering" of asphalts, may offer a clue as to the formation of the pits. Oxygen dissolved in the waters percolating through the strata in which this specimen was embedded, might account for a local oxidation of the tar as it emerged from the pores of the eggshell, the carbon dioxide formed producing an initial solution of the material of the capsule. As soon as the matrix was appreciably dissolved, the tar was forced into the new-formed

cavity and the action began again. Since the oxidation would take place over the whole surface of the minute drop exuding from the pore in the shell, the cavity formed would naturally assume the spherical shape which these pits possess.

The Bituminous Material.

The tar is a semifluid substance of very dark brown color, resembling natural asphalts in appearance and physical properties. At 10° C. it is brittle, showing a conchoidal fracture with brilliant surfaces, the edges of the fracture becoming rounded on standing. As the temperature rises it grows softer, until at 100° C. it becomes a fluid with considerable viscosity. Its specific gravity is a trifle less than that of boiling water. It is readily and completely soluble in petroleum ether, turpentine, carbon disulphide and chloroform; much less in acetone and ether, and only very slightly soluble in alcohol even when boiling. No residue of an organic or inorganic nature is left by any of these solvents. In all of these points it resembles the "petroleum-ether-soluble" fraction of all natural asphalts, long known as "petrolene."

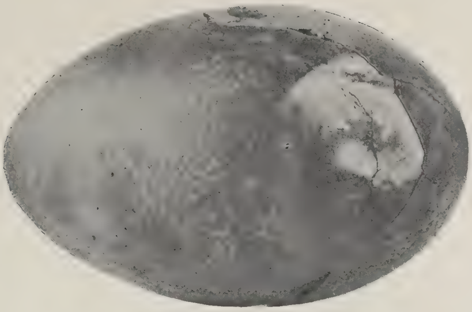
In cold fuming nitric acid it is soluble, separating partially a jelly-like mass which resembles silicic acid. If the solution be now poured into water a flocculent precipitate separates, resembling aluminum hydroxide colored slightly with ferric hydroxide. This precipitate is soluble in fuming nitric acid.

If the solution of tar in nitric acid be heated, the jelly-like substance dissolves, and is not completely oxidized by evaporating to dryness. On boiling the residue with dilute nitric acid everything dissolves as the acid concentrates, and when poured into water now gives a flocculent red precipitate like ferric hydroxide, to which reference is made by Day,* in his investigation of gilsonite. This ferric-hydrate-like precipitate, on being heated with water, collects as a thick reddish oil, very slightly soluble in petroleum ether, but readily soluble in alcohol, especially when warmed, thus showing it to be a different body from the original tar.

Concentrated sulphuric acid dissolves the tarry material also, giving a dark red-brown solution which, on treatment with water, gives a precipitate similar to that from fuming nitric acid just described.

By the sodium nitroprusside reaction the tar gives qualitative tests for the presence of sulphur. A comparison of the intensity of color given by tests made on the tar with similar solutions containing known amounts of sodium sulphide would indicate about 0·2 per cent of sulphur in the tar. How much of the total amount present in the tar would escape conversion into

* Jour. Franklin Institute, cxl, p. 239 (1895).



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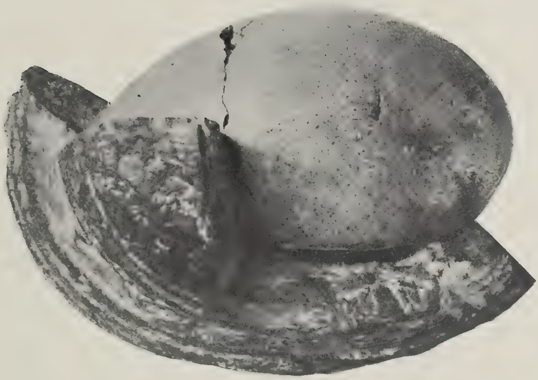

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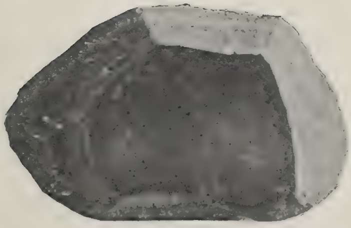

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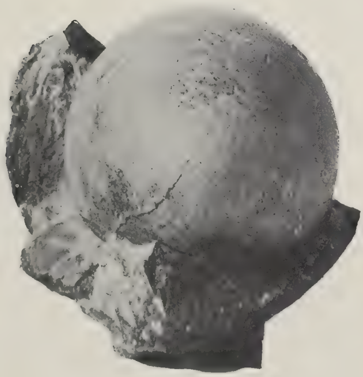

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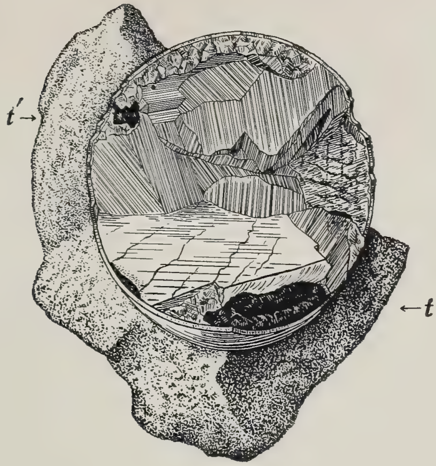

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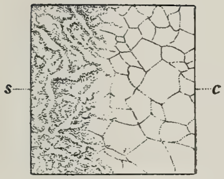

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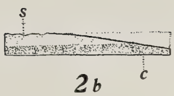

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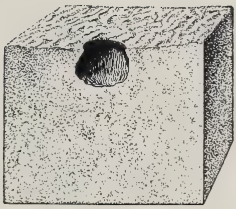

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alkaline sulphide by heating with metallic sodium is a matter of conjecture only, but it is probable that less than 1 per cent of the tar is sulphur.

Tests for nitrogen, by heating with sodium and precipitating the cyanide as Prussian blue, failed to indicate the presence of this element even when 0·3 gram of tar was treated. Under these circumstances the resulting solutions gave very strong tests for sulphur but not a particle of the blue precipitate could be obtained even on long standing.

In order to ascertain the delicacy of this method of detecting nitrogen in substances of a nature similar to those which might be expected to be present in the tar, qualitative experiments were made with known amounts of pyridine and quinoline. It was found that 0·01 gram of either substance would give a precipitate in such quantity that when diluted to 100^{ccm} and thoroughly mixed, 1^{ccm} would on settling give a distinct indication. Similar results were obtained by mixing the same amounts of pyridine with the tar and then heating with sodium. Certain natural asphalts known to contain nitrogen were tested by this method and gave positive results. Hence it is concluded that the failure to obtain evidence of nitrogen in the present instance was not due to the method. While heating the pyridine with sodium its odor was very apparent in the room, and since it is the most volatile member of this series of compounds it seems highly probable that if nitrogen were present in the tar to the extent of 0·05 per cent it would have been detected.

No evidence of phosphorus could be found, after oxidizing with fuming nitric acid and testing with molybdate solution.

None of the properties, either physical or chemical, which have thus far been set forth, indicate any difference between this tar and some pure natural asphalts.

A combustion of 0·1107 gram of the tar for carbon and hydrogen gave 0·2582 gram carbon dioxide and 0·1058 gram water, indicating 63·6 per cent carbon and 10·6 per cent water. These figures give 25·8 per cent oxygen and other elements, determined by difference. Since nitrogen is absent and sulphur present only in small amounts, oxygen seems to form about one-quarter of the entire substance.

These percentages do not agree even remotely with the figures given by asphalts, which show generally less than 5 per cent of oxygen. Incomplete combustion may possibly explain this discrepancy but there was no evidence of this during the progress of the combustion. Although a second determination was greatly desirable, the material for it was not at hand.

It is interesting to note in this connection, however, that certain bituminous substances have been reported as containing

a much greater percentage of oxygen than the figures in the present case. According to Schrötter* dopplerite contains 43·03 per cent oxygen. Elaterite appears to be associated sometimes with substances of high oxygen content, which makes the amount of oxygen present in the unpurified material run as high as 35 or 40 per cent.

On heating above 100° C. many natural asphalts and "breas" froth very characteristically because of the water contained in them. Inasmuch as no frothing occurs on heating this tar to 150° C. it is concluded that it contains no appreciable amount of water. This conclusion is supported by the fact that the petroleum ether, chloroform and carbon disulphide solutions are perfectly clear, showing not the slightest turbidity, a circumstance hardly probable if water were present chemically uncombined in the specimen.

As the temperature is raised above 100° C. the tar begins to decompose slowly. At 150° C. the action is very decided. A volume of inflammable gas, large in proportion to the weight of the substance heated, is liberated. This reaction is completed between 200° C. and 250° C. after which but little decomposition ensues until the temperature rises above that indicated on an ordinary thermometer.

An attempt was made to determine the boiling-point of the oily liquid left after such heating. It remained unchanged at 300° C., and, on heating the tube with a small flame, would creep away from the hotter portions without visibly boiling at 360° C.

The substance remaining after heating to 250° C., on cooling, resembles the original tar in appearance. It is, however, no longer completely soluble in petroleum ether. Only about two-thirds are dissolved by this solvent. Most of the remainder is soluble in carbon disulphide but there always remained a distinct residue which could only be dissolved in chloroform. In these solubility relations it resembles ordinary asphalt possessing a large "petroleum-ether-soluble fraction" ("petrolene") and a smaller "asphaltene" fraction soluble in carbon disulphide. The portion soluble only in chloroform is thought by Pecham† to be an indication of "weathering" in those asphalts in which it occurs in appreciable amounts. In this instance it is clearly formed by the action of heat. A combustion of 0·0405 gram of the material heated as described gave 0·1257 gram carbon dioxide and 0·0452 gram water, indicating 84·7 per cent carbon, 12·4 per cent hydrogen and about 3 per cent of oxygen and sulphur. These percentages correspond with the figures given by asphalts generally on combustion.

* Wien., Akad. Ber., 285 (1849).
† Jour. Franklin Institute, No. cli, pp. 114–124 (1901).

In short, this material can not be differentiated from ordinary natural asphalt in any way. It would appear that the tar as it exists in the fossil has not been completely bituminized, since it apparently contains considerably more oxygen than bituminous bodies generally possess. On heating to 150° C. the transformation is completed and the resulting product is in all respects a typical asphalt. The ready decomposition of the tar and the entire change in its composition and nature after being heated to 150° C. offer evidence that the specimen has never been heated to this temperature previously.

When the asphalt thus formed is heated to a dull red heat more gas is liberated, doubtless due to "cracking" of the high-boiling oils constituting it, and a residue resembling coke is left.

The Matrix.

The matrix in which the egg is embedded varies from a little less than half an inch to nearly an inch in thickness, and consists of a fine-grained gray limestone, readily effervescing when treated with dilute hydrochloric acid. A quantitative analysis was deemed unnecessary. Qualitatively examined, it gives slight tests for iron, aluminum, silicic and boric acids, the relative amounts being in the order named. Magnesium is present in larger quantity. No tests for sulphates, phosphates or chlorides were obtained. In short, the matrix seems to be a limestone of considerable purity. It shows no geological evidence of metamorphism whatever.

In an indentation in one side of the limestone is a small deposit of very fine hard clay, indicating that at some time during its history the fossil embedded in its limestone capsule has been buried under such conditions as to allow the formation of clay about it.

On being fractured, especially when crushed in a mortar, the limestone gives off the peculiar fetid odor supposed to be due to the presence of organic matter. On dissolving in hydrochloric acid an odor similar to that produced when iron and zinc are treated with acids becomes apparent, and a slight greasy scum is evident on the surface of the liquid when in a test-tube. The intensity of these phenomena is not greater than is observed frequently in limestones containing no appreciable amounts of organic matter.

In order to ascertain the nature and amounts of this organic matter present, a piece of the matrix weighing about 10 grams was extracted with petroleum ether to remove the tar filling the pits and covering the inner surface. The piece was then finely powdered and extracted again with boiling chloroform. Upon evaporation, from 9·7380 grams of the matrix 0·006 gram of tar similar to the other tarry material was obtained.

To ascertain whether this tar could be extracted from all sections of the matrix or was found alone in those layers nearest the center, pieces of the limestone from three different sections of the outer layers of the matrix, removed as far as possible from the fossil itself, were powdered and extracted similarly but no weighable residue was obtained from any portion. This indicates that the carbonaceous material soluble in chloroform is not distributed evenly throughout the matrix but is confined to the layers in the immediate neighborhood of the tar-filled fossil. Since the amount of tar extracted from the matrix previously mentioned represents only about 0·06 per cent of the weight of the limestone, inasmuch as the extracted material seems identical with the tar found inside the egg and covering the shell, it is believed that this amount was some of the same material from inside the shell which was not extracted by the solvent previous to grinding. Therefore it is believed that the matrix as a whole contains no carbonaceous matter of a bituminous nature.

To ascertain whether the matrix contains appreciable amounts of carbonaceous matter which will become bituminous on heating, about 10 grams of the limestone were heated in a hard glass tube in an atmosphere of carbon dioxide. The products of the ignition were passed through a freezing mixture to collect any liquid distillate and the gas was collected over potassium hydroxide solution. On heating beyond the limit of a thermometer reading to 360° C., only 3^{ccm} of gas were collected. On withdrawing the thermometer and raising the temperature to dull redness, 7^{ccm} more gas collected during a half-hour's heating, when the hard glass tube fused and blew out. Nothing but a drop or two of water condensed in the freezing mixture. Thinking that the gas which had collected might be air a taper was applied, when a slight explosion ensued, showing that a part only of the 10^{ccm} of gas was combustible.

Assuming the combustible gas to have been entirely methane, 10^{ccm} would weigh 0·007 gram. In reality the amount of combustible gas could not have been half this figure, since it exploded on the application of a taper. Since extraction of the heated limestone with boiling carbon disulphide left no weighable amount of material, it is safe to say that the matrix does not contain more than 0·02 or 0·03 per cent of carbonaceous matter of a pyrobituminous nature.

On examining the limestone left in the tube it seemed to be somewhat lighter in color. On being sprinkled on red litmus paper moistened with water, the color changed to blue, showing that the temperature had been sufficiently high to "burn" some of the limestone in an atmosphere of carbon dioxide and make it caustic. On being treated with acids it no longer

liberated the fetid odor previously mentioned, but left behind small amounts of a very voluminous insoluble black residue, largely carbonaceous, which from 1 gram of the ignited material did not exceed 0·0006 gram. Since the analysis of many "stinking" limestones, barites, cherts and quartz failed to show the presence of carbonaceous matter, it seems safe to say that the limestone composing the matrix by which the egg was surrounded does not contain as much as 0·1 per cent of carbonaceous matter. Furthermore, this small amount is of a pyrobituminous rather than a bituminous nature, requiring a temperature of approximately 800° C. to decompose it into gaseous decomposition products.

Evidence as to Origin.

In seeking for an adequate source of the tar present within the egg the most satisfactory answer may be obtained by the method of exclusion. The specimen was found in a region from which very few deposits of bituminous substances have been reported. It is necessary to assume that the colemanite came in from outside in solution, percolating through the matrix. The detection of boric acid in the limestone is, therefore, what would naturally be expected. If the very insoluble tar had come in through the matrix in a similar manner, it would be highly reasonable to expect to detect its presence, also, in the matrix. No tar was found except in the layer immediately in contact with the shell, where all evidence goes to show that the movement has been in the contrary direction, i. e., from within toward the exterior. In short, no evidence has been discovered to indicate that the tar came in from without.

On the other hand, there is considerable evidence to indicate that the tar could hardly have come in from an outside source. The tar is entirely too viscous to have come in its present condition through the solid matrix surrounding the egg. It is possible that it might have passed through the matrix dissolved in a lighter solvent which has since disappeared. In this case, after entering the egg, as the solvent evaporated the solution must have concentrated and tended to collect in one deposit on the bottom of the cavity. But there are several deposits of the material within the eggshell, some being diametrically opposite the main body of material which is assumed to have collected on the floor of the cavity. Similarly, the distribution of the tar inside the shell, coupled with its ready decomposability when heated, forbids the possibility of its having entered from without in the gaseous state. Considering the properties of the tarry material, there seems to be no reasonable possibility that it could have come in from an

external source, and have been deposited as it now is inside the eggshell.

Evidence of an adequate source for the tar in the limestone in which the fossil was embedded seems to be entirely wanting. There is no bituminous matter in the matrix, neither is there an appreciable quantity of any pyrobituminous material. Moreover, the ready decomposability of the tar with the formation of a product insoluble in petroleum ether indicates clearly that the temperature of its surroundings could never have been as high as 150° C. But at this temperature there was no evidence at all of pyrobituminous material, since the small amount of gas produced was liberated only at a red heat.

Considering the indubitable evidence that the tar was present before the colemanite came in, the small amount of bituminous matter present inside the shell, rather than an egg filled full of the material, is not without its significance.

Considering the highly fragile nature of an egg and the perfect state of its preservation, the conclusion that it was encased very soon after it was laid seems inevitable. This must mean the inclusion of its natural contents.

There is no reason to suppose that the egg of any previously existent bird, the shell of which is so similar to present day specimens as to be indistinguishable even under the microscope, would differ materially in the chemical nature of its contents.

In the eggs of the various families of birds which have been analyzed, there is but a slight variation in the relative proportions of the constituents, a difference not sufficient to invalidate the present considerations. The average composition of the edible portion of ducks' or geese's eggs may be taken as 15·5 per cent protein and 14·5 per cent fat. Very probably these figures closely represent the composition of water birds' eggs as a whole. The cubical contents of the fossil egg is 49^{ccm}. Assuming the specific gravity of its natural contents to have been 1 (it is usually a trifle greater), there would be about 7·5 grams of fat and somewhat more of dry protein. Assuming that the protein would lose all of its nitrogen and sulphur as ammonia and hydrogen sulphide or their equivalents, and that part of its carbon would disappear as the monoxide or dioxide or their equivalents, 40 per cent of the dry weight of protein would still remain if these decompositions took place without the intervention of oxygen from without. Under the same circumstances more than 90 per cent of the fat would still remain. There is, of course, the probability of a decomposition resulting in the formation of methane, but of the magnitude of this reaction no inferences can be drawn or allowances made. The assumption of

5 or 6 grams of residue from the contents of an egg of the size of the present specimen is not, therefore, unduly large.

It is difficult to estimate closely the amount of tar present in the fossil because of its varying distribution. The total quantity of bituminous matter could not have been more than 3 grams and was probably much nearer 2 grams. This amount might well have been derived from the fat alone. The absence of nitrogen in the bitumen may possible be accounted for by the suggestion that the easily decomposable protein may have entirely disappeared, while the more stable fatty constituents may alone have become bituminized.

The derivation of the tar from the original contents of the egg is, then, entirely possible, and from what is known of the process of bituminization its origin from such a source, under the conditions to which it has doubtless been subjected, is not in the least improbable. In the absence of any evidence to the contrary, therefore, since extraneous sources have been shown to be highly improbable, no reasonable ground seems to exist for doubting that the tar now present in the fossil has been derived from the natural contents of the egg.

Bearing.

After more than seventy years of painstaking investigation from the purely scientific as well as technical sides, the matter of the origin of bitumens is still an open question in many respects. Three entirely distinct theories have been before the world for years, ascribing their origin to three separate and distinct sources. The laboratory investigations of Moissan, especially for the theory of inorganic origin, and of Warren, Daubrée, Engler, Day and Sadtler for the organic side, have made it apparent that the results of experimentation support any theory and that artificial production indicates only the possibilities and not necessarily the realities as to the origin of bitumens.

Furthermore, every case of artificial production of bituminous matter has required a temperature much beyond the ordinary, a condition which an examination of natural deposits seems to render exceedingly improbable. "What geologists would be glad to find in Nature," says Professor Orton,* "as matching to and harmonizing with the facts with which they are obliged to reckon, would be a process in which the products of the organic world are transformed into mineral oil at ordinary temperatures with complete consumption of the substances acted upon so that no carbon residue would be left behind. They would also expect the transformation to be accomplished while

*Bull. Geol. Soc. Am., 9-90 (1898).

the organic matter still retained essentially its original character."

The attempt has been made repeatedly to realize these condition,—to ascertain whether unquestioned evidence could not be obtained to show from what kind of matter natural deposits have actually been derived. Many natural deposits have been carefully examined, but in no case can the evidence be considered as conclusive.

Thus, Wall pronounced the celebrated "pitch lake" of Trinidad to be of vegetable origin because of the remains of vegetation in all stages of transition which are present in the pitch. Jones found in the same pitch unquestionable animal remains; hence an animal origin is not improbable. Later Richardson* examined the "lake" and concluded that the conditions present offer "a far more reasonable basis for the assumption of a volcanic origin."

Fraas observed petroleum oozing from a coral reef in the Red Sea and concluded that the coral polyps are to-day being changed into bitumen. Binney noticed the same phenomenon about a peat bog in England and inferred that peat was being transformed at the present time into petroleum. Both of these are isolated instances. No other known coral reefs or peat bogs show evidence of similar changes, although conditions seem to be identical. Neither occurrence was thoroughly studied to ascertain what evidence there might be for or against the possibility of another origin. Neither instance is to be regarded, therefore, as unquestionable.

The occurrence of bitumen in fossils has hitherto been of no value as a means of furnishing direct evidence as to its origin, inasmuch as investigation proves that the bitumen need not, and often could not, have been derived from the organism with the remains of which it is to-day associated.

The discovery of the present specimen, a fossil egg partly filled with bituminous material, is under these circumstances of scientific value. For while absolute proof cannot be given, the evidence amounts almost to a demonstration that the bituminous substance now present in the egg represents a part of its original organic contents. In the absence of any evidence to the contrary we may accept that origin toward which all the evidence points. This specimen presents, then, one of the very few instances, possibly the only one, in which conclusive evidence is at hand to connect bituminous matter with the original material from which it has been derived by a natural process without abnormal conditions.

The absence of nitrogen from a bitumen material can not be regarded, therefore, as unquestioned evidence of its vegetable

* Jour. Am. Chem. Soc., 7-51 (1893).

origin, neither should the association of bitumen with boric acid be considered as a strong indication of volcanic origin for the bitumen.

University of California, Berkeley, California.

EXPLANATION OF PLATE XVIII.

FIGURE 1.—Side view of egg.
FIGURE 2.—Egg in the original matrix.
FIGURE 3.—Matrix from inner side, showing pits.
FIGURE 4.—In the matrix, end view.
(All figures natural size.)

Measurements.

Length of egg	62mm
Width " "	40
Circumference (longitudinally)	169
" (transversely)	124
Long diameter of enclosing capsule	120
Average thickness of enclosing capsule	12
Thickness of eggshell	·33

EXPLANATION OF PLATE XIX.

FIGURE 1.—Fractured surface of the broken egg, showing the contents; *t*, *t′*, and other darkened areas represent the bituminous material; the remainder of the cavity is filled with colemanite. (Natural size.)

FIGURE 2*a*.—A portion of the eggshell ground down on one side. *s*, corrugated outer surface: *c*, cellular lower layer. (×275.)

FIGURE 2*b*.—Cross-section of the shell fragment shown in figure 2*a*. *s*, corrugated outer surface; *c*, cellular lower layer. (×275.)

FIGURE 3.—Outer surface of the shell, showing corrugations of the surface and a large pit filled with bituminous material. (×275.)

FIGURE 4.—Cross-section of the pit shown in figure 3. (×275.)

Art. XL.—*On the Radio-activity of Natural Waters*; by Bertram B. Boltwood.

The occurrence, in the water of the public supply of Cambridge and the water from a number of other English localities, of a radio-active gas having properties similar to those of the radium emanation, has been demonstrated by J. J. Thomson* and confirmed by E. P. Adams.† Bumstead and Wheeler‡ have also shown that a similar radio-active gas is contained in the city water supply of New Haven, Conn., and in water from a spring at New Milford, Conn. That the waters from the hot springs at Bath and Buxton in England also contain radio-active gases has been demonstrated by Allen and Blythswood,§ who examined the gases given off at the springs and also the gases which escape from the water on boiling. The presence of minute quantities of radium salts in these waters and also in the sedimentary deposits formed at the point of issue, which has been observed by Strutt,‖ is of considerable importance since it has been shown by Rayleigh¶ that the gases which rise with the springs consist in part of helium.

Mention is made by Himstedt** of the occurrence of radium emanation in the waters of the thermal springs at Baden-Baden, Germany, and an examination by Elster and Geitel†† of the sedimentary deposits formed at these springs, has made it evident that these deposits contain radium compounds.

Curie and Laborde‡‡ have recently tested the gases given off at certain mineral springs of European origin and by the waters of these springs on boiling. They examined gases from nineteen different sources, fourteen of which they found to be radio-active. The radio-active properties of the gases corresponded to those of the radium emanation.§§

Radium emanation has also been found to occur in crude petroleum and natural gas, as well as in the air drawn from the ground in a number of different localities.

The object of this paper is to describe a method for the quantitative determination of the radio-active gas contained in a water and to furnish a convenient standard for measurement and comparison; also to offer some experimental evidence as to the origin of the radio-active properties of natural waters.

* Nature, lxvii, 609 (1903); Proc. Cambr. Phil. Soc., xii, 172 (1903).
† Phil. Mag., viii, 563 (1903).
‡ This Journal, xvi, 328 (1903); ibid., xvii, 97 (1904).
§ Nature, lviii, 343 (1903); ibid., lxix, 247 (1904).
‖ Proc. Royal Soc. London, lxxiii, 191 (1904).
¶ Proc. Royal Soc. London, lx, 56.
** Ann. d. Physik, xiii, 573 (1904).
†† Physikal. Ztschr., v, 321 (1904).
‡‡ Compt. Rend., cxxxviii, 1150 (1904).
§§ H. Mache, Physik. Ztschr., v, 441 (1904).

Method of Determination.

The gases dissolved in a water can be conveniently separated and collected by the method described by Reichhardt.* The apparatus as ordinarily constructed is too small for the purpose under consideration and requires certain modifications. It consists (fig. 1) of a vessel *A* made from sheet copper and having a capacity of about 9 liters. The orifice of this vessel, 9^{cm} in diameter, is surrounded by a heavy brass ring, 15^{cm} in outside diameter, to which can be attached by clamps a heavy brass

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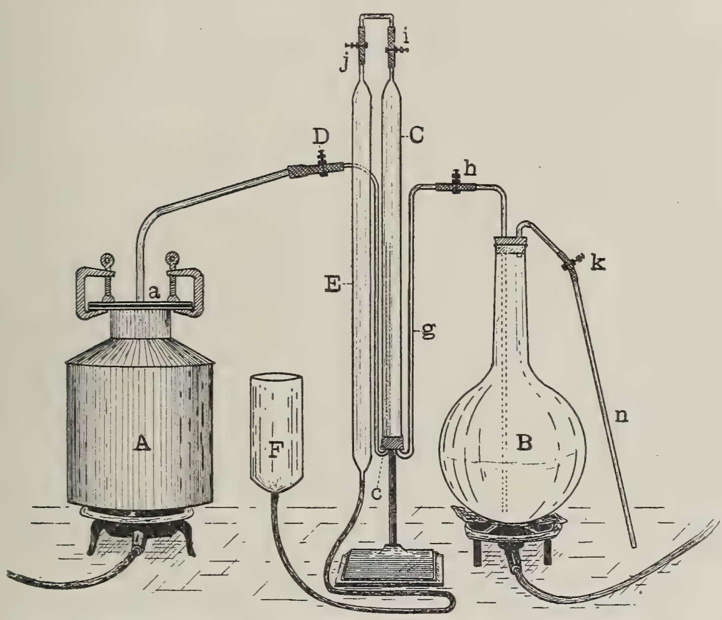

plate *a*, having a block-tin pipe soldered into an opening in its center. A rubber gasket, 3^{mm} thick, between the plate and the ring makes the joint perfectly tight when the clamps (6 in number) are screwed up tightly. A piece of thick-walled rubber tubing carrying a screw-pinchcock *D* connects the tin pipe with the glass tube *c*, which extends to the gas receiver *C*. This latter is 52^{cm} in length and 3^{cm} in diameter and has a total capacity of about 350^{cc}. The tube *c* protrudes about 20^{cm} into *C* beyond the rubber stopper at the bottom. The top of *C* is drawn out into a short, narrow tube and is closed by a rubber tube and a screw-pinchcock, *i*. The tube *g* passes from the bottom of *C* and is joined at *h*, by a piece of rubber tubing carrying a screw-pinchcock, to a glass tube which passes through a rubber stopper and extends to the bottom of the

*Hempel's "Gas Analysis" (translated by L. M. Dennis).

flask B. This flask has a capacity of about four liters. Through the stopper which closes it, there also passes a short glass tube attached by a short rubber tube to the glass tube n. The end of n dips into a good-sized beaker. The contents of A and B can be brought to boiling by the heat from two large gas-burners placed below the vessels.

In making a separation of gas, the flask B is first filled about one-half full of distilled water, which is boiled vigorously for about fifteen minutes. In the mean time the vessel A is completely filled with the water to be tested, the cover a placed in position and secured by the clamps, the rubber tube D disconnected from the tin pipe, and the pinchcocks are all opened. At the end of the 15 minute interval the pinchcock k is closed, when the pressure of the steam in B will force the boiling water from B into C and the tubing connected with it. When these are completely filled with the hot water, the pinchcocks D and i are closed and the cock k is opened. The tin pipe attached to a is now filled full of distilled water and the rubber tube D is slipped over it. The pinchcock D is then opened and the gas lighted in the burner under A.

The gas burette E, filled with distilled water, is connected with i by a short piece of capillary tubing, and the screw-pinchcock j is opened. As the temperature of the water in A approaches the boiling-point, the gas is freely disengaged and, passing through the tube c, accumulates in the upper part of the gas receiver C. By lowering the balance-receptacle F and opening the cock i the gas can be transferred from time to time to the burette E. The water in A is boiled gently for about 20 minutes. By a proper regulation of the pinchcock at k and the burner under A the pressure within the apparatus can be so regulated that the height of the water column in C is about 10 centimeters. The pinchcock at h is used in emergencies when the water in A, having become slightly superheated, tends to boil too vigorously and the excess of steam threatens to force the accumulated gas out of C into B. In such cases the cock h is closed, the gas under A turned off and the cock i opened, permitting the excess of vapor to pass over into E.

Since natural waters almost always contain an excess of carbon dioxide gas, a few cubic centimeters of a strong solution of sodium hydroxide is added on introducing the sample into A. This combines with the free carbon dioxide and reduces the volume of gas set free on boiling.

After all the gas obtained from a given sample of water has been transferred to the burette E, it is introduced into an air-tight electroscope. This operation is carried out in the following manner:

The air in the electroscope is exhausted until the pressure is about one-half atmosphere. To one of the stopcocks of the electroscope a small T-tube is attached by a short length of rubber tubing. The branch of the T-tube connected with the rubber tube contains a filling of granulated, anhydrous calcium chloride held between plugs of cotton wool. The rubber tube *j* of the gas burette is slipped over another branch of the T-tube, and the third branch is closed by a short rubber tube plugged with a glass rod. The pinchcock *j* is first opened and then the stopcock of the electroscope is opened, so that the gas is drawn very slowly into the electroscope. When the water in the burette has risen to the junction of the side tube, the pinchcock *j* is closed and the plug removed from the side tube, permitting the external air to pass into the electroscope and sweep with it any of the gases from *E* remaining in the tube and connections. When the atmospheric pressure is established in the electroscope the stopcock is closed and the apparatus disconnected.

In the tests which will be described later in this paper the average volume of gas obtained was about 150^{cc}. The capacity of the electroscope used was about 530^{cc}, so that under the conditions which have been described about 100^{cc} of atmospheric air swept through the connecting tubes before the normal pressure was established in the interior of the electroscope.

The activity of the gas from the water was measured in the electroscope, which has been described in a previous paper.* The gold leaf was charged by a battery consisting of 216 small, lead storage cells, at a potential, therefore, of about 432 volts. The positive terminal of the battery was earthed and connected with the case of the instrument; the negative terminal was connected with the top of the rod supporting the gold-leaf. The normal air-leak of the instrument was low and quite constant, and was equal to approximately 0·012 division per minute. The readings obtained with each measurement of gas were corrected by this quantity.

Because of the initial rise in the activity when the emanation is first introduced into the electroscope, due to the formation of "emanation X" on the walls of the vessel, the rate of leak at the end of three hours was taken as the measure of the activity.

Standard.

One of the most important points in the measurement of the radio-activity of the gas contained in a water is that the results shall be given in the terms of some standard which will permit the direct comparison of the results obtained by different experimenters. In the investigations conducted by

* This Journal, xviii, 97 (1904).

Curie and Laborde the standard adopted is the quantity of emanation produced by one milligram of pure radium bromide in one second. Such a standard would suffice for all immediate needs if it were not for the fact that it is impossible for others to obtain at present even small quantities of radium bromide of known and established purity. Other investigators have adopted the plan of expressing the activity in terms of the number of ions produced per second in a volume of one cubic centimeter. This is difficult to determine with accuracy and its indirect calculation is uncertain.

The standard here suggested and employed is the quantity of radium emanation set free when a known weight of uranium in the form of a natural mineral is dissolved in a suitable reagent.* The mineral which has been used is a pure uraninite from North Carolina. It was dissolved in aqua-regia, the solution diluted with water and the gas removed by boiling. The details of the operation follow:

The sample of uraninite was finely pulverized in an agate mortar. A portion on analysis was found to contain 82·46 per cent of uranium. A quantity of the pulverized mineral equal to 0·0121 was weighed out into a small tube made by cutting off about 4^{cm} of the bottom of an ordinary glass test-tube. The tube was lowered by means of a short piece of common thread into a flask of about 100^{cc} capacity, which had been previously filled about one-half full of distilled water. A rubber stopper with which the flask could be closed carried a glass tube, which could be pushed through the stopper until the lower end was just above the surface of the water in the flask. Beyond the stopper the tube was bent at a right angle. The stopper was placed very loosely in the neck of the flask, the tube which it carried being at the same time inserted in the top of the tube containing the mineral. On releasing the end of the thread at the right moment this dropped into the flask, leaving the tube floating on the water and supported in an upright position by the fixed tube within it. The rubber stopper was then tightly inserted in the neck of the flask and about one cubic centimeter of aqua-regia was introduced into the tube containing the mineral, a small pipette with a long, thin, capillary tube being used for this purpose.

The open end of the tube was then connected with the rubber tube *D* (fig. 1), the vessel *A* having been removed. The pinchcock *D* was opened, the flask and contents were warmed gently and the uraninite was dissolved. When the solution of the mineral was complete the tube extending into the flask was drawn out through the rubber stopper until the opening was just below the stopper. This permitted the tube containing

* This Journal, xviii, 97 (1904).

the solution of the mineral to fall on its side and fill with water. The contents of the flask were now boiled for about 20 minutes, a few snips of platinum foil having been placed in the flask to prevent bumping. The gases which accumulated in the tube *C* were transferred to the gas burette *E*, allowed to stand for 15 minutes and then introduced into the electroscope. The water in the flask *B*, the tube *C* and the gas burette *E* contained a little sodium hydroxide to absorb any chlorine which might be produced in the reaction. The time which transpired from the boiling off of the gas to its introduction into the electroscope (about 30 minutes) was sufficient to reduce the activity of the thorium and actinium emanations also present to a negligible value.

The rate of leak as determined at the end of three hours was taken as the basis of calculation, and was considered as equal to the activity of the radium emanation associated with 0·0100 gram of uranium. This leak was equal to 1·76 division per minute. A fall of the gold-leaf equal to 0·001 division per minute was therefore equivalent to $5{\cdot}68 \times 10^{-6}$ grams uranium.

Calculation of Initial Activity.

In most cases it is either impractical or altogether impossible to carry out the measurement of the activity of the water at the source of the spring. A certain length of time, either a few hours or several days, must elapse between the time of collection of the sample and the time that the test is conducted. Since it is highly probable that the activity of most, if not all, radio-active waters is due *chiefly* to dissolved radium emanation, this activity will become regularly less on standing. The decay of the radium emanation will follow the simple exponential law expressed by the equation:

$$I = I_0 e^{-at},$$

in which I represents the activity after the interval t, I_0 the initial activity, e the base of the Napierian system of logarithms and t the elapsed time expressed in hours. The value of the constant a is 0·00724 as determined by Curie, 0·00778 as determined by Rutherford and Soddy, and 0·00744 as determined by Bumstead and Wheeler.*

The initial activity of the water can therefore be calculated from the observed value of I. A convenient form of the equation is then

$$I_0 = I e^{at.}$$

Radium Salts in Solution.

The presence or absence of radium salts in solution can be demonstrated by boiling about 10 liters of the water, a little

* This Journal xvii, 97 (1904).

acetic acid being added to prevent the precipitation of carbonates. After boiling, the water is allowed to stand for several hours in contact with the air and is then introduced into a bottle and tightly sealed. The capacity of the bottle should be such that the water completely fills it, leaving only the smallest possible air space below the stopper. The water is then allowed to stand for a sufficient length of time (say 16 days) and is then boiled again in the apparatus shown in fig. 1. If radium salts are present in the water, the gases given off on this second boiling will contain the accumulated radium emanation, and the relative quantity of radium present can be calculated from the observed activity of the gas.

Radio-active Waters.

A considerable number of samples of radio-active waters have been examined by the method herein described. Data on only three of these is at present available. The sources of these three samples were the following:

No. 1. Water from a spring at Windham, Me. This spring is known as the "Maine Granite Spring," and is stated to issue from a granite and sandstone formation, to have an estimated flow of 100 gallons per minute and to have a temperature of 43° Fahr. throughout the year. This sample was tested four days from the time of collection and was obtained through the courtesy of Prof. Chas. F. Mabery.

No. 2. Water from a spring in one of the public parks of the city of New Haven, known as "Cold Spring." The formation immediately adjacent to the spring is red sandstone, and the temperature of this spring on September 5, 1904, was 52° Fahr. The flow is small.

No. 3. Water of the city supply in New Haven, drawn from the pipes in the laboratory.

The radio-activity of the gases from these samples is given in the table which follows:

Table.

Sample No.	Liters taken.	Leak measured.	Leak per liter.	I.	I_0.	
1	8·9	9·91	1·11	63·22	128·6	calculated.
2	8·9	0·61	0·068	----	3·9	measured.
3	8·9	0·0036	0·0004	----	0·025	"

The leak is expressed in divisions per minute, the values of I and I_0 are expressed in terms of grams uranium $\times 10^{-4}$ per liter of water. The value given for No. 3 is the mean of three separate determinations. The value of the constant, *a*, employed in the calculation was that determined by Bumstead and Wheeler.

Samples Nos. 1 and 2 were tested for radium salts in solution with negative results. It has been shown by Bumstead and Wheeler that no radium salts are present in the New Haven water (No. 3).

The radio-active properties of the gases from the first two samples were carefully examined and were found to correspond with those of the radium emanation. The activity fell to one-half in approximately four days and the rate of decay of the excited activity agreed with that of the "emanation X" from radium.

Origin of the Radio-active Properties.

The following experiments were carried out with a view to determining the possible source of the radio-active properties in the waters.

A quantity of uranium minerals was pulverized in an iron mortar and passed through a 100-mesh sieve. The minerals consisted chiefly of uranophane, but contained also some gummite, autunite and a small quantity of uraninite. The greater quantity of the material represented the final decomposition-product of uraninite when subjected to the action of percolating waters. The material taken weighed 80 grams. It was placed in a flask and about 500^{cc} of distilled water were poured over it. The contents of the flask were mixed thoroughly and allowed to stand, with occasional shaking, for about twenty-four hours. Some of the mineral was in such a fine state of division that the water remained very turbid after standing undisturbed over night.

The mineral was filtered off on a Buchner filter and the filtrate was boiled (to expel emanation). The water was cooled, introduced into a two-liter bottle with glass stopper, diluted with distilled water until the bottle was quite full and the stopper tightly inserted. The water was allowed to stand for four days, and the gases which it contained were then boiled off and tested in the electroscope. The activity of the gas was equivalent to 0·016 division per minute.

After filtering off the water as described above, the powdered minerals were washed twice with distilled water and the excess of water removed by suction. 100^{cc} of cold distilled water were then poured over the mass on the filter and drawn through it, this filtrate being separately collected. The filtrate was allowed to stand in an open beaker for one-half hour and was then boiled, the gases given off being collected and introduced into the electroscope. The leak at the end of three hours was 0·240 division per minute.

The mineral powder on the filter was washed back into the

flask and about 500^{cc} of water added. The water was boiled for three hours. The mineral was then filtered off and the filtrate boiled for one-half hour. The filtrate was diluted, sealed up for four days and then boiled again. The gases given off were tested for radio-activity in the electroscope and the observed leak was 0·034 division per minute.

About 80 grams of the same mineral mixture but in coarser powder had been shut up in a flask for about eight days. A sample of the gas in the flask withdrawn and separately tested showed that the total accumulated emanation in the flask had an activity equivalent to approximately 1700 divisions per minute. The gas was drawn from the flask into a 4-liter bottle by allowing the water with which the bottle was filled to run out until only about two liters remained. The bottle was then closed and shaken vigorously for about five minutes, and was then allowed to stand undisturbed for about thirty minutes. Water was then run into the bottle until all of the gas was displaced, the gas being collected in a second bottle (see below). Care was taken to remove any small bubbles of gas adhering to the neck of the bottle, and the water it contained was then introduced into the boiling can. The gases were boiled out of the water and tested in the electroscope. The activity of the gas obtained was equivalent to 80 divisions per minute.

The second bottle mentioned above, having a capacity of four liters, was filled one-half full of the gas from the first bottle, the gas being introduced at the top, while the water with which it was at first filled was permitted to flow out through a tube reaching to the bottom. Care was taken to avoid any agitation of the water and the gas was allowed to stand in contact with it for about two hours. The bottle was then completely filled with water by means of a tube reaching to the bottom and the gas was displaced. The activity of the gas obtained from the water on boiling was equivalent to a leak of 0·40 division per minute.

Summary.

From the results of these experiments it is apparent that by the action of cold, pure water on the uranium minerals used only a very slight trace of the radium contained in them is dissolved. The action of hot water is only slightly greater than that of cold water. Even brief contact with uranium minerals can impart to water very marked radio-active properties due to dissolved radium emanation. Water can also acquire very readily measurable quantities of radium emanation by simple contact with gaseous mixtures containing the emanation.

On applying these data to the occurrence of natural radio-active waters, it would seem as if all the observed facts could be readily explained. An extremely minute trace of uranium minerals in the rocks and soil through which the waters percolate in their underground passage would be sufficient to impart to them radio-active properties, which could be readily detected by the sensitive method at command. It can be anticipated that waters which rise through strata containing appreciable quantities of uranium minerals will be found more highly radio-active than any which have thus far been described. The results obtained from the examination of waters from springs in well-known uranium localities can be looked forward to with interest.

In those cases, at Bath and at Baden-Baden, where the waters have been found to carry traces of radium in solution, it can safely be assumed that the decomposing action of the waters due to their high temperature is still further increased by the pressure and by the fact that they contain various chemical substances in solution. These latter, while they promote the decomposition of minerals, may also retard the removal of the radium through the formation of insoluble sulphates, phosphates, etc. The fact that these waters on reaching the surface almost immediately deposit the greater portion of their radium is indicative of the difficulty with which that element is retained in solution.

In view of the extraordinary sensitiveness of the radio-active test for the radium emanation, it is very surprising that samples of gases from four of the springs examined by Curie and Laborde were found by them to be quite inactive.

139 Orange St., New Haven, Conn.,
October 11, 1904.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *On the Action of Radium Emanations on Diamond.*— Having previously shown that diamonds, when exposed to the impact of radiant matter in a high vacuum, become blackened from a superficial coating of graphite, Sir William Crookes has recently experimented upon the action of the rays from radium upon these gems. Two diamonds having the same pale yellow color were selected, and one of them was kept for a fortnight close to a quartz tube containing 15 mg. of radium bromide sealed *in vacuo*. Comparison of the exposed diamond with the one not exposed showed no appreciable difference in color, and the same result was obtained after six weeks of exposure. The diamond phosphoresced brightly and continued to glow during the whole period of the experiment. The previously exposed diamond was now put inside a tube with radium bromide, the salt touching it on all sides, as it was thought possible that a screen of quartz might interfere with the passage of emanations which would act on the diamond. After a continuation of this exposure for seventy-eight days, the diamond had a darker appearance than the one reserved for comparison, and it showed a bluish green tint with no apparent yellow color. It thus appears that radium emanations, which darken glass in a marked manner, and quartz to a slighter extent, are also capable of darkening the diamond. The exposed diamond was now treated for ten days with mixtures of the strongest nitric acid and potassium chlorate, for the purpose of testing for a superficial formation of graphite. It was evident that graphite had been present, for the diamond lost its dull surface color and was as bright and transparent as the other stone, but its tint had changed from yellow to a pale blue-green.

The conclusion is reached that the radium emanations have a double action on the diamond. The β-rays (electrons) exert a superficial darkening, converting the surface into graphite in a manner similar to, but less strongly than, the more intense electrons in the cathode stream. But the alteration of the body color of the stone by emanations which are obstructed by the thinnest film of solid matter, even by a piece of thin paper, is not so easy to understand. It is believed that the alteration of color is a secondary effect, connected with the extremely phosphorescent state of the diamond during its exposure. It is not difficult to suppose that a chemical as well as a physical action may result. If the yellow color is due to iron in the ferric state, a reduction to the ferrous state would account for the change of color to a pale blue-green. This alteration of color may be of commercial importance in treating "off color" stones.

After the exposed diamond had been treated for ten days with the acid mixture, it was carried about with its unexposed com-

panion for about twenty-five days, and then both were laid together on a sensitive film for twenty-four hours. On development, the exposed diamond was found to have impressed a strong image on the film, but only a faint mark could be seen where the other stone had been. A repetition of the experiment confirmed the result.—*Chem. News.* xc, 1. H. L. W.

2. *Radio-active Lead, Radio-tellurium, and Polonium.*—DEBIERNE has arrived at the conclusion that the radio-active lead of Hofmann and Strauss and the radio-tellurium of Marckwald are identical with M. and Mdme. Curie's polonium. The radiation of polonium is distinct from that of uranium, thorium, radium and actinium, and consists entirely of the almost non-penetrating α-rays, which are only slightly affected by a magnet. The radio-active substances which accompany bismuth, lead, and tellurium are all precipitated from acid solutions by hydrogen sulphide, and they have all been derived from pitchblende.

Having at his disposal a large amount of the residues from the extraction of radium, Debierne tried to obtain ratio-active lead. The lead nitrate obtained had a radio-activity only about twice that of uranium. Recrystallization of this nitrate was not effective in concentrating the radio-active substance, but when a large excess of hydrochloric acid was added to a concentrated solution of this nitrate, lead chloride crystallized out, leaving nearly all the radio-activity in solution. By repeating this operation several times the non-active lead chloride was eliminated, and the greater part of the activity was concentrated in a small quantity of matter. This portion, consisting chiefly of lead, was purified from small traces of copper and iron, and then transformed into nitrate. Upon adding the concentrated, slightly acid, solution of this nitrate to a large quantity of water, a very slight precipitate of basic bismuth nitrate was formed, which contained nearly all the radio-activity, and corresponded to very active poloniferous bismuth. The active matter thus obtained also showed all the properties of radio-tellurium; its solution gave an active precipitate with stannous chloride, and an extremely radio-active coating upon a thin piece of metallic bismuth.

It is thus seen that the same radio-active substance shows successively properties characteristic of radio-active lead, polonium, and radio-tellurium. The conclusion to be drawn is that there is no distinction between these three bodies, and it is evident from these experiments that a radio-active substance cannot be identified by chemical reactions, since analytical separations merely cause it to be shared among the different fractions. The only certain test is the nature of the radio-activity, and the identity of the radiations given by polonium, radio-active lead and tellurium would in itself predict the results that have been reached.

Circumstances were such that the lead nitrate used in these investigations was kept for three years before the work was completed. During this time it retained all of its feeble activity, although samples of polonium prepared from it gradually lost

this property. The author believes that the constancy of the activity must depend upon external conditions which it will be very important to determine, and he suggests the possibility that under certain conditions the activity of other substances, such as uranium, thorium, radium, and actinium, will diminish and disappear in the same manner as that of polonium.—*Comptes Rendus*, cxxxix, 283. H. L. W.

3. *Condensation of Helium and Hydrogen by Charcoal.*—As a continuation of his studies on the condensation of gases by charcoal,* Sir James Dewar has obtained some interesting results with hydrogen and helium. Two discharge-tubes, provided with small condensers containing 1 or 2 g. of wood charcoal were filled, one with hydrogen and the other with helium at atmospheric pressure. The little charcoal condensers were now plunged into liquid hydrogen, with the result that the vacuum became so high that no electric discharge would pass in the tube filled with hydrogen, while in the tube containing helium the vacuum was high enough to obtain the phenomenon of phosphorescence under the action of the discharge. Two similar tubes containing helium from different sources were then subjected to the action of liquid hydrogen boiling under exhaustion, which produced a temperature of 15° absolute. In each case the vacuum resulting from the occlusion of the helium was so high that a coil giving a spark of 4^{cm} in air had to be used to obtain an intermittent phosphorescent discharge. From comparative experiments with hydrogen and helium it is concluded that the boiling point of helium is about 6° absolute.—*Comptes Rendus*, cxxxix, 421. H. L. W.

4. *Die Riechstoffe;* von Dr. Georg Cohen. 8vo, pp. 219. Braunschweig, 1904 (Vieweg und Sohn).—This book deals with those organic products—synthetical and natural—that are distinguished by some characteristic odor, particularly those which have found commercial application in the manufacture of perfumes. A great number of synthetical products are described, including alcohols, ethers, esters, aldehydes, ketones, and bases; and the reactions by which each class can be identified are discussed. A part of the book is devoted to tables relating to the numerous ethereal oils; their physical constants and chemical compositions are given, together with the names of the plants from which the oils are obtained. A short discussion of the relation between odor and chemical constitution is also given. The references to patent literature are very full. While the book will be of little interest to the theoretical chemist, it will be of use to the technical chemist who is interested in the manufacture of perfumes. T. B. J.

5. *Volumetric Analysis;* by Francis Sutton. Ninth edition, revised and enlarged. 8vo, pp. 617. Philadelphia, 1904 (P. Blakiston's Son & Co.).—This standard work on volumetric analysis is so universally known among English-speaking chemists

* See this volume, pp. 290 and 295.

that the appearance of this new edition requires no comment, except the statement that it contains some important changes and additions. H. L. W.

6. *Emanation of Radium.* — Sir WILLIAM RAMSAY from a careful study of this emanation concludes that it behaves like an ordinary gas resembling the gases of the argon family. It is luminous and obeys Boyle's law. A table of wave lengths of its spectrum is given. The gas is probably monatomic with a density of about 80 and an atomic weight of 160. Its electrons cannot be made to penetrate other bodies. The name *Exradio* is proposed for this gas.— *Comptes Rendus,* June 6, 1904, pp. 1388–1394. J. T.

7. *Emanations—Radiations.*—BERTHELOT suggests that surface films of volatile substances may account for many of the observed phenomena of radio-activity. In this connection the smell of metals is significant.— *Comptes Rendus,* June 20, 1904, pp. 1553–1555. J. T.

8. *Conduction of Electricity through high Vacua.*—Hon. R. J. STRUTT believes from his experiments that, even in high vacua, there is a loss of electricity from a charged body, in presence of the α-rays, independent of traces of residual gas. A rod of bismuth was made radio-active by a deposit of radio-tellurium which emitted α-rays only. The rod was attached to an electroscope. The exhaustion was pushed to the degree that no discharge could be forced through a Röntgen tube connected with the apparatus. The leak seemed to be distinct from that which is due to the ordinary ionization of gases. The author believes that the leak results from the particles torn off from the bismuth by the issuing α-ray. No details are given in regard to the character of suspension of the rod.—*Phil. Mag.*, Aug., 1904, pp. 157–158. J. T.

9. *Negative Ions from Heated Metals and Oxides.* — Many observers have studied the formation of positive or negative ions on heated metals. A. WEHNELT has shown that not only metals but a large number of metallic oxides possess the same property and to a much higher degree than the metals. He continues his investigation in this article and sums up his results as follows :

If platinum foil is covered with the oxides of the earth alkali (Ca, Ba and Sr) the cathode fall of potential is much lessened, from the numerous negative ions which are emitted. It was found at atmospheric pressure that negative ions issued even at a dark red heat from the oxides, while pure platinum held negative ions even at a very high temperature. In a vacuum the oxides and also pure platinum emitted negative ions, the number of which increased with the temperature. With the oxides the number of ions was 1000 times greater than with platinum. Calculation showed that the negative ions per volume-unit of the metallic oxide are 100 times greater than the number of the molecules in the same volume, so that one must assume that to each molecule of the oxide numerous negative ions are combined. The lessen-

ing of the cathode fall when glowing metallic oxides are used is due to emission of negative ions. By means of this property of emission very strong currents can be sent through a gas even at low pressures.—*Ann. der Physik*, No. 8, 1904, pp. 425–468.

J. T.

10. *Electro-chemical Equivalent of Silver.*—Determinations of this constant has been made by the following observers:

Mascart	0·011156
F. and W. Kohlrausch	0·011183
Lord Rayleigh and Mrs. Sidgwick	0·011179
Pellat and Potier	0·011192
Kahle	0·011183
Patterson and Guthe	0·011192
Pellat and Leduc	0·011195

The last determination with, it is claimed, more accurate determinations of the horizontal intensity of the earth's magnetism, the strength of the electrical current and the time, has been made by G. Van Dijk and J. Kunst, who have obtained the value

$$a = 0,\ 0111823 \pm 0{\cdot}0000004 \text{ (m.F.)}$$

From the agreement of observations, this result is claimed to be accurate to $\frac{1}{10,000}$.—*Ann. der Physik*, No. 8, 1904, pp. 569–577.

J. T.

11. *Electric Effect of Rotating a Dielectric in a Magnetic Field.* — According to Maxwell's Electromagnetic Theory, an electromotive force should be induced in a dielectric and its amount—according to Lamor and Lorentz—should be $(1-K^{-1})$ times that in a conductor, K being the permittivity of the dielectric. H. A. Wilson has shown the existence of this effect by rotating a hollow cylinder of ebonite in a magnetic field, parallel to the axis of the cylinder, with suitable conducting brushes, the results of the experiment were as follows :

(1) A radial electric displacement, is produced in the dielectric when it is rotated in a magnetic field parallel to the axis of revolution.

(2) The direction of the displacement is the same as is produced in a conductor.

(3) The displacement is proportional to the magnetic field and to the rate of revolution.

(4) The amount of the displacement agrees with that calculated on the assumption that the induced E.M.F. in the dielectric is equal to that in a conductor multiplied by $(1-K^{-1})$.—*Proc. Roy. Soc.*, June 22, 1904, pp. 490–492. J. T.

12. *A Radio-active Gas from Crude Petroleum.*—E. F. Burton shows that fresh crude petroleum contains a strongly radio-active gas similar in its rate of decay and in that of the induced radioactivity to the emanation from radium and to the emanations obtained by various experimenters from mercury and from certain waters fresh from the earth. This radio-active gas decays approximately according to an exponential law, falling to half

value in 3·125 days. It produces an induced radio-activity, whose rate of decay is such that it falls to a half value in about 35 minutes. There are indications of the existence in crude petroleum of slight traces of a radio-active substance more persistent than the radium emanation.—*Phil. Mag.*, October, 1904, pp. 498–508.

13. *Absorption of Water Vapor in the Infra-red Solar Spectrum.*—F. E. Fowle, Jr., in No. 1, vol. II, of the Quarterly issue of the Smithsonian Miscellaneous Collection, details the results of a bolographic study, made at the Smithsonian Astrophysical Observatory, of the absorption of water vapor in the infra-red region of the solar spectrum. It is shown that "the selective absorption of water vapor, within the range of densities observed, seems to depend only on the amount of the absorbent present and is well expressed by Bouguer's formula. In other words, the absorption produced by a given quantity of water in the form of vapor, is the same whether the path is great through a small density or vice versa. Considering successive bands, for example $0·81\mu$, $\rho\sigma\tau$, Φ, Ψ, Ω, it may be noted that the selective absorption of water vapor is not greatest like the general absorption at the shorter wave-lengths, but increases as the wave-lengths of the bands increase. It varies from 10 per cent in the more shallow bands near A, at $0·76\mu$, to nearly 100 per cent in the bottom of Ω at $1·80\mu$, when only on exceedingly dry days is much indication of energy detected. However, in the separate bands themselves, when the increase in absorption on reaching the bands from the shorter wave lengths side is quite sudden, the absorption then more slowly decreases like the general absorption with increasing wave lengths."

14. *On the Action of Wood on a Photographic Plate in the Dark.* — Continuing his work on the action of various substances upon a photographic plate, W. J. Russell shows that this property probably belongs to all wood, some kinds, however, being much more active than others. The sample of wood must remain in contact with, or at a little distance from, the sensitive plate for a time varying from 30 minutes to 18 hours; the temperature must not be above 55° C. The wood of conifers is very active and gives definite pictures. A section of a branch of Scotch fir gave an excellent picture showing the rings of both spring and autumn growth; the former were very active and produced dark rings in the picture, the latter were inactive. If, as has been suggested, hydrogen peroxide, present in the resin, is the cause of the action, it is necessary to assume that the resin in the dark (autumn) rings is under such conditions that it cannot escape.

Pine wood acted in the same way as the fir; also the spruces, but with them the action is less definite and sharply marked, and in some cases the dark rings were also active. With larch wood the picture is the reverse of that of the fir, the dark rings being active, the light rings inactive. Of other woods, oak, beech,

acacia, Spanish chestnut and sycamore were active, while the ash, elm, horse chestnut and plane wood were comparatively but slightly active. Exposure to bright sunlight for a short time (5 to 10 minutes) served to intensify to a high degree the action of the active parts ; this is true of all wood. This increased action lingers for a considerable time ; red glass, however, prevents this increase of activity.—*Proc. Roy. Soc.*, lxxiv, 131.

I. Geology and Mineralogy.

1. *U. S. Geological Survey.* — The following publications have recently been issued :

Latrobe Folio, Penn., No. 110 ; by M. R. Campbell. The Latrobe district is in the midst of the Pennsylvania coal area and its general geologic structure and economic importance have long been known. There is, however, little discussion of physiographic history in the Pennsylvania reports, and it is particularly in this regard that the recent work of Mr. Campbell adds to our knowledge of Western Pennsylvania.

The Schooley peneplain is recognized in the summit of Chestnut Ridge. The Harrisburg peneplain, cut in the Schooley plain when the land stood 1200 feet lower than at present, is recognized here as well as in the Monongahela and Susquehanna Valleys. The Harrisburg peneplain is Early Tertiary. A still lower level is described as the Worthington peneplain. The broad valley floor of the Conemaugh, which is such a conspicuous feature between Blairsville and Tunnelton, is found to correspond to similar features on the Monongahela, Youghioheny and Allegheny rivers, and to date from pre-Quaternary times. This feature is described as the Parker strath. The abandoned channels and oxbows of these rivers are believed to be the results of ice dams in early Glacial time, and not connected with the draining of Lake Monongahela as suggested by Dr. I. C. White. The streams of this district flowed directly toward the ice front and with the advent of spring the ice melted first at the head of the stream. There was thus opportunity for many ice dams, temporary, or even continuing through several seasons. This hypothesis accounts for many abandoned channels in Western Pennsylvania, which otherwise are inexplicable.

Zinc and Lead Deposits of Northern Arkansas : by George I. Adams, assisted by A. H. Purdue and E. F. Burchard ; with a section on the Determination and Correlation of Formations, by E. O. Ulrich, 115 pp., 27 pls., 6 figs., Professional Paper No. 24. In addition to the economic study of the lead and zinc deposits of northern Arkansas, Mr. George I. Adams presents a sketch on the geologic and physiographic history of that region. A number of faults already noticed by the Arkansas geological survey are described and proof given that they are normal faults and not thrust faults, as considered by Branner. A description is given of the brecciated dolomite

of the Yellville formation. The brecciation is believed to be due to pressure induced at the time of the folding in the Ouachita Mountain Ranges. Movements which resulted in folding and thrust-faulting in the Ouachita Mountains and open folding in the Arkansas Valley region are represented in the southern portion of the Ozark district by brecciation of individual beds without disturbing their horizontal position.

A Geological Reconnaissance across the Bitterroot Range and Clearwater Mountains in Montana and Idaho; by Waldemar Lindgren. 116 pp. 15 pls. 8 figs. Professional Paper No. 27.—The Bitterroot Valley is one of the most striking typographic features in the western part of the United States. It is two to nine miles broad, runs almost exactly north and south, and is depressed 5,000 feet below the deeply incised Bitterroot Range to the west. The structure of this valley and of the adjoining mountains has been worked out by Mr. Lindgren, and shows some remarkable and unique facts. The depression owes its existence to the normal fault, but the essential feature of this dislocation is the fact that the fault plane corresponds with the schistosity and jointing, so that there is every gradation between the molecular and molar motions, indicating that both result from the same forces. In the sheared zone there is "intimate and inseparable relation between schistosity and faulting." The striated slipping planes of the granite-schists are closely massed, as many as twelve of them sometimes occurring in a thickness of one inch. This locality would seem to be an excellent one to test the divergent views regarding schistosity and jointing. Mr. Lindgren thinks that the observations of the Bitterroot Range confirm the opinions of Mr. G. F. Becker: that there is no essential difference between jointing cleavage and schistosity, that they may both be produced at the same time, and that molecular movement is not necessarily confined to the zone of flowage. The Bitterroot Range forms one of the largest glacial areas known in the Cordilleras. Excellent illustrations of U-shaped valleys, cirques, and various glacial deposits occur throughout the Range.

2. *Baraboo Iron-bearing District, Wisconsin*; by Samuel Weidman. Wis. Geol. and Nat. History Survey, Bull. No. 13, 171 pp., 23 pls., 3 figs. The Baraboo district, Wisconsin, shows an interesting geological series, consisting of pre-Cambrian igneous and pre-Cambrian sedimentary and of Paleozoic strata. The iron ore is hematite developed from original limonite, and it is an interesting fact that the ores showed no surface outcrop but were found by drilling through sandstone and drift. In order to get at the iron ore it was necessary to understand the geological structure of the pre-Cambrian quartzite (Baraboo). A detailed study of the quartzite shows that its structure consists of a double syncline, on the top of which is deposited unconformably Potsdam sandstone. The hypotheses of Irving, and later of Salisbury, are shown not to be in accordance with the facts.

3. *Chemical Survey of the Waters of Illinois;* by A. W. PALMER, 243 pp. 52 pls.—The factors which make for and against a satisfactory water supply of a state and the relation of geologic structure to these factors are emphasized by the recent report of the Illinois Water Survey. A study has been made of the sanitary condition of the waters of lakes, streams, and wells, as shown by 460 analysis. Particular attention has been devoted to the Illinois River during 1897–1902, and it has been found that the waters of that stream, where they enter the Mississippi, contain less organic matter than previous to the construction of the Chicago Sanitary Canal. A chapter on the Geology of Illinois as related to its water supply is written by Professor Rolfe.

4. *Submerged Tributary of the St. Lawrence.*—In the Transactions of the Royal Society of Canada, vol. ix, Section iv, pp. 143–147, H. S. POOLE publishes a chart and description of an ancient river system with headwaters in Pictou County, Nova Scotia, and receiving important tributaries from Prince Edward, Magdalen, and Cape Breton Islands. The river follows closely the ridges of hard rock near shore, and submerged mounds suggest a continuation seaward of the Carboniferous coast terrace. The presence of this river maintaining its characteristic features through several sub-cycles is sufficient to account for the absence east of Pictou and along Cape Breton of the softer members of the Carboniferous series, without assuming fault boundaries.

5. *Sands and Sediments;* by T. MELLARD READE and PHILIP HOLLAND (Proc. Liverpool Geol. Soc., 1903–04, pp. 3–20).—An investigation has been begun to find out whether there exists any relation between the size of the particles or grains of sand and their chemical constituents; also the degree of minuteness to which particles can be ultimately reduced by natural agencies, and how, and in what way this takes place. These investigations, when completed, will indicate in some degree how far purely mechanical sediments may be carried out and deposited in the ocean. An inquiry is also being made into the question of the origin of limestone by the deposition of infinitesimal particles carried out from the land. The investigations so far give "hints of the possibility of deep-sea limestone being formed in an inorganic way."

6. *Palæontologia Universalis.*—The writer desires to call the attention of American Geologists to the fact that this very important work has but 21 subscribers in the United States, while France has 63 and Germany 96. Certainly the geologists and geological libraries of this country are not yet supplied with this publication. Fasciculi I and II have been issued; these contain 97 sheets redescribing and refiguring 46 of the old and little known species.

It is intended to issue annually from 150 to 160 sheets, treating of about 80 species. The annual subcription price is $8.00. Subcriptions may be sent to G. E. Stechert, No. 9 East 16th street, New York City. Those persons or institutions desiring further information regarding this work, with samples of the plates, will

be supplied on application to Professor Charles Schuchert, Yale University Musem, New Haven, Conn. CHARLES SCHUCHERT.

7. *Interferenz-Erscheinungen im polarisirten Licht; photographisch aufgenommen;* von Dr. HANS HAUSWALDT in Magdeburg. Neue Folge, 1904.—The series of eighty beautiful plates contained in this work forms a very valuable aid to the study of the behavior of crystal sections in polarized light, in fact so excellent are the photographic reproductions that, except for the absence of color, the student can learn almost everything from them that he could from the specimens themselves. This work follows the "Interferenz-erscheinungen an doppeltbrechenden Krystalle im convergenten polarisirten Licht" published two years since by the same author, while still further plates are promised in the future. The plan of the series now issued has been made by Professor Liebisch of Göttingen, to whom the work is dedicated; Dr. Siedentopf, of the optical works of Carl Zeiss in Jena, has also contributed materially to the success of the enterprise in various directions. The execution of the plates (by Studders and Kohl of Leipzig) leaves nothing to be desired.

A complete statement of all that is given in this series would require the reproduction in full of the table of contents. The opening plates exhibit the axial figures for several species (calcite, topaz, gypsum, albite) in converging polarized light as modified by the aperture of the condenser (C_1 and C_2 with num. ap.$=0{\cdot}636$ and $1{\cdot}168$ in each case). Then follow a number of plates showing the limiting curves of the complete interference figures in converging light for calcite and quartz under varying conditions.

The influence of the color of the light source is shown for calcite, quartz, cerussite and titanite, wave-lengths of 620–$720\mu\mu$ and 410–$450\mu\mu$ respectively being used in each case. Other plates show the dispersion of the optic axes of brookite for different colors; the effect produced by the combinations of mica plates of Reusch and of Noerrenberg; the interference bands of wedges of birefringent crystals in parallel polarized light; the spectral analysis of the interference colors of sections of birefringent crystals; the anomalous optical characters of beryl and the peculiar phenomena yielded by boracite, leucite, perofskite, also garnet, milarite and other species. Twin structure is exhibited for numerous species; also spherolitic structure; further, the birefringent phenomena called out in glass by rapid cooling and by pressure, and the effect of change of temperature and pressure in the case of crystals of various species. Finally, absorption phenomena are fully illustrated.

This summary will serve to show the great variety of phenomena exhibited by the upwards of three hundred figures of this unique work.

8. *Tableau systematique des Minéraux classés d'apprès leurs propriétés chimiques et cristallographiques;* par P. GROTH. *Traduit de la quatrième édition allemande* par MM. E. JOUKOWSKY et F. A. PEARCE. Avec corrections et additions de l'auteur. Préface

par Louis Duparc. Pp. viii, 188. Geneva, 1904 (Grebel, Wendler & Cie., Éditeurs).—French students are to be congratulated in having placed before them this translation of Professor Groth's admirable work, a work which occupies a unique place in mineralogical literature and which has exerted a great influence upon the progress of the science since the publication of the first edition thirty years since.

9. *An Introduction to the Study of Meteorites, with a list of the Meteorites represented in the Collection of the British Museum of Natural History on January 1, 1904;* by L. FLETCHER. Pp. 109, London, 1904.—The last edition of this guide to the meteorite collection of the British Museum, with its interesting introduction, was issued in 1896. Since that time the collection has increased notably, the total number of specimens recorded at the beginning of the present year being 557.

10. *Manual of the Chemical Analysis of Rocks;* by H. S. WASHINGTON. Pp. 183, 8vo. New York, 1904 (John Wiley & Sons).—The author states that the object of this book is to present to chemists, mining engineers, petrologists and others who have not made a particular study of quantitative analysis, a selection of methods for the chemical analysis of silicate rocks and especially those of igneous origin. There are probably few branches of science in which a greater amount of earnest, well intentioned work has been done in the last twenty-five years, with so much that is inaccurate and of little value in results, as in petrography in the making of rock analyses. They have, in large part, been made by beginners or by those having little skill, experience or knowledge of correct methods, with a corresponding loss of time and effort. A particularly bad feature of the case is, that it is not always evident or possible, contrary to what generally obtains in pure mineral analysis, to determine how inaccurate the results are. In these later years, however, a change has taken place in this respect and as high a standard of analytical excellence is now demanded in petrography as in any other branch of science.

Several causes have contributed to this result, especially the efforts of a number of earnest workers, among whom are to be chiefly mentioned the chemists of the United States Geological Survey as well as the author of this book.

On the other hand it may be said that there are not many things, when one considers the number of elements to be determined and the length of the processes involved, which demand greater skill and experience in analysis from the chemist than that of silicate rocks.

All this makes the appearance of this work a very timely one and it will be henceforth an almost indispensable adjunct to the library of every analytical chemist and petrographer. The author gives in full detail a description of the necessary apparatus, reagents, etc., and of the proper method of selecting material. The analytical processes selected are those which long

experience has shown to be the best, and the methods for carrying them out are so fully described, that with the attentive use of the work, even beginners may achieve good results, while the experienced analyst will find much that is of interest and value in saving time and work. It is well and clearly written and the field has been thoroughly covered. It is to be hoped that its appearance will do much to raise the standard in this field of scientific work. L. V. P.

11. *Notes on the Rocks of Nugsuaks Peninsula and its environs, Greenland;* by W. C. PHELAN. Smith Misc. Coll., Quar. Issue, vol. 45, pp. 183–212. 1904.—The author has made a study of a collection gathered by Professor Schuchert and Dr. David White. The collection embraced types of gneiss, diorite, syenite, peridotite, monzonite, granite and basalt, the latter containing native iron. Detailed petrographic descriptions of these are given and of several, complete chemical analyses were made. The paper adds considerably to our knowledge of the petrography of Greenland and will be read with interest by petrographers. L. V. P.

12. *Ueber den Kali-Syenit des Piz Giuf und Umgebung und seine Ganggefolgschaft;* von F. WEBER. Beitr. zur Geol. Karte der Schweiz Neu. Folge XIV Leif. Bern, 1904, 4°, 176 pp., pl. V.—The rock masses described in this paper lie in the western part of the Aar massive. The main mass of syenite forms a long slender lens in granitic rocks, about 13 kilometers long and bent slightly into an S shape. It is accompanied by dikes of more salic and femic characters. There are also varieties of the main syenite type. All these rocks, under the headings of syenite, aplite, granite porphyry, spessartite and kersantite, have been thoroughly studied and analyzed and the results are here presented, together with discussions of their relationships, origin, and the bearing of these on the general question of differentiation. It is an extended and careful piece of work which adds to our knowledge of local Swiss petrology and contains much of general interest to petrographers. L. V. P.

III. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *Harvard College Observatory.*—Recent publications of the Harvard College Observatory include the following:

ANNALS, vol. xlvi, Part II, pp. 121–249, with plates I, II, Observations of Variable Stars made with the Meridian Photometer during the years 1892–1898; by Edward C. Pickering. Vol. liii, No. III, pp. 45–73 with plates I, II. The ninth Satellite of Saturn; by William H. Pickering. This paper gives a most interesting account of the search, begun in 1888, for the supposed ninth satellite of Saturn, and its identification in 1899 on photographs taken the year previous at Arequipa. Later observations have served to determine with accuracy the orbit of Phœbe, as the satellite has been called. It is found to have an eccentricity greater than that of any other planet or satellite and is exceeded

only by a few of the asteroids. The period is 546·5 days and its diameter is estimated at 200 miles. It is thus the largest body discovered in the solar system, exclusive of the comets, since the inner satellites of Uranus were found by Lassell in 1851; it is also by far the faintest object, its brightness being estimated as two magnitudes less than that of Hyperion, which is assumed to be of the 14th magnitude.

Vol. liii, No. IV, pp. 75–84 with four plates. A Study of Eratosthenes; by William H. Pickering. Some paragraphs from this paper are quoted below.

Vol. lvi, No. I, pp. 1–26 with two plates. Distribution of Stellar Spectra.

Circulars: No. 83, Common's 60-inch Telescope; No. 84, Carnegie Grant of 1903; No. 85, The anonymous gift of 1902.

2. *A Study of a Lunar Crater.* — The following paragraphs, which form the concluding part of the "Study of Eratosthenes" by W. H. Pickering, referred to above, will be read with interest in connection with the recent discussion of the features of the moon (see p. 314 of the October number). The author closes the detailed description of the crater and the changes in it observed by him as follows:

"Summarizing our knowledge so far, we find that there seem to be four canal systems, two large and two small. They are best seen in figure 11. In each there is a prominent lake from which three or more canals diverge in various directions. The largest of these lakes, which we will call I, is situated to the east of the central peaks. Three canals radiate from it. The second largest, which we will call II, is situated on the northwestern slopes of the central peaks. It also has three canals. III, at the extremity of ridge *A*, has four or five canals radiating from it, and a nearly concentric ring, similar to *Solis Lacus* on Mars. IV is a small and very faint lake at the extreme northern end of the floor, from which at least five minute canals radiate. It also is furnished with a somewhat ill-defined dark ring, composed in part of the lakes and canals of systems I and II. I reminds us somewhat of the *Syrtis Major* on Mars and the two large canals or branches which lead into it from the south, and form a rather characteristic Y at certain seasons.

These canal systems seem to be almost entirely independent of the surface configurations. Sometimes the central lake is on a mountain crest like III, and sometimes in the bottom of a valley like I. The canals sometimes, as in system II, descend one slope, cross a valley, and ascend another. They generally appear all at once throughout their whole length, but in at least two instances we have recognized a progressive motion. In one of these cases, *A*, the direction of motion was tangential to the lake III; in the other, *D*, it was radial and towards the lake I. In both cases the motion was down hill. *D* vanished on the ridge before it did on the lower slopes.

A few words may now be said on the chief objection that has been raised to the theory that these changes are due to vegeta-

tion, namely, the lack of water on the Moon. While it is true that water cannot exist in the free state under a pressure that is less than 4·6 millimeters, and while it is also true that no such pressure apparently exists upon the Moon's surface, still there is nothing to prevent water occurring beneath the surface of the ground, retained by the capillary action of the soil. It has been shown by Cameron (Science, 1903, xviii, 758) that water can be extracted by dry soil from a membrane against a calculated osmotic pressure of 36 atmospheres, or about 500 pounds per square inch. Since on the Earth plants can live on moisture which they have in turn extracted from such a soil, there seems no difficulty in understanding how they could live on the Moon, in a soil which could thus retain considerable moisture in spite of the low atmospheric pressure. Indeed if it were possible to conceive of an organism which could absorb its oxygen directly from vegetation, and store it during the lunar night, there is no reason why animal life should be impossible upon the Moon.

That the substance which we have called vegetation is frequently found in connection with deep clefts has already been pointed out by the author, in dealing with the crater Franklin, see "The Moon," page 56. That a dark patch of vegetation sometimes covers an area formerly occupied by ice has been shown in the case of Riccioli in the Harvard Annals, xxxii, 216. Finally, that different areas of vegetation in the same crater may appear and disappear at quite different times has been pointed out in the case of Alphonsus, in the Annals, xxxii, 33. It therefore appears that the various phenomena above described have all been indicated before in visual observations made at this Observatory. Their interest here lies chiefly in the fact that in Eratosthenes they are shown so clearly, and upon so large a scale, that we are now able to photograph them. We are thus able to share with other astronomers what in the case of visual observations can only be seen by those who have good enough atmospheric conditions to be able to detect them. In the case of visual observations other persons must place their faith on the judgment and accuracy of the observer, in the present case the photographs permit every reader to be his own observer and judge."

3. *Field Columbian Museum, Publication 95, Zoological Series,* vol. IV, parts I and II, pp. xx, 850, with sixty-eight plates and numerous text-figures.—These volumes are devoted to the "Land and Sea Mammals of Middle America and the West Indies," by Daniel Giraud Elliot. This admirable work follows the "Synopsis of the Mammals of North America and Adjacent Seas" by the same author and is intended to contain all the mammals of the remainder of the North American Continent, that is from the northern boundary of Mexico to the Province of Cauca, South America, including the coast islands, also part of Bahamas and West Indies. It is clearly presented and very fully illustrated.

4. *Statistical Methods with special reference to Biological Variation;* by C. B. Davenport. Second, revised edition, pp.

viii, 223. New York 1904 (John Wiley & Sons).—The first edition of this useful work was issued in 1899 (see this Journal, viii, 399). A second edition, somewhat enlarged, is now given to the public; the most important addition is that of the new statistical methods of Prof. Karl Pearson, his students and associates, with a summary of the results gained by them.

5. *Catalogus Mammalium, tam viventium quam fossilium;* a Doctore E.-L. Trouessart. Quinquennale Supplementum, anno 1904. Berlin (R. Friedländer u. Sohn).—Fasciculus II, pp. 289–546, of the Supplement announced in the July number of this Journal (p. 94), has recently appeared. It is devoted to the Rodentia.

6. *Beitraege zur Chemischen Physiologie und Pathologie;* herausgegeben von Franz Hofmeister. Band V. Braunschweig, 1904 (Fr. Vieweg und Sohn).—The present volume of fifty pages is, like its predecessors, largely taken up with investigations on the proteids and their derivatives. A contribution by Dr. Kammann on the specific pollen toxin which gives rise to hay-fever, indicates that the poison belongs to the group of toxalbumins, is thermostable and not completely destroyed by proteolytic enzymes. These facts are of interest in connection with the recent attempts to induce immunity to hay-fever and to obtain a specific antitoxin. Various papers on blood-coagulation serve to render the explanation of this process more complex than ever before. Professor Röhmann has contributed an interesting paper on the skin glands (Bürzeldrüsen) of birds, throwing considerable light on the origin and composition of the secretion which they yield. The volume also contains several papers of physico-chemical interest, and a number of communications on enzymes, including important observations on amide-splitting ferments. L. B. M.

7. *Ostwald's Klassiker der exakten Wissenschaften.* Leipzig, 1904 (Wilhelm Engelmann).—The following parts of this series of scientific classics have recently appeared.

No. 143. Abhandlung über die Auflösung der numerischen Gleichungen (1835) von C. Sturm. Aus dem Französischen übersetzt und herausgegeben von Alfred Loewy. Pp. 66.

No. 144. Johannes Keplers Dioptrik, oder Schilderung der Folgen, die sich aus der unläugst gemachten Erfindung der Fernrohre für das Sehen und die sichtbaren Gegenstände ergeben (1611). Ubersetzt und herausgegeben von Ferdinand Plehn. Pp. 114.

No. 145. Über die Konstitution und die Metamorphosen der chemischen Verbindungen und über die chemische Natur des Kohlenstoffs: untersuchungen über aromatische Verbindungen von August Kekulé. Herausgegeben von A. Ladenburg. Pp. 89 with a plate.

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Established by BENJAMIN SILLIMAN in 1818.

THE AMERICAN JOURNAL OF SCIENCE.

FOURTH SERIES.

VOL. XVIII—[WHOLE NUMBER, CLXVIII.]

No. 108.—DECEMBER, 1904.

WITH PLATE XX.

NEW HAVEN, CONNECTICUT.

1904

THE TUTTLE, MOREHOUSE & TAYLOR CO., PRINTERS, 123 TEMPLE STREET.

Published monthly. Six dollars per year, in advance. $6.40 to countries in the Postal Union. Remittances should be made either by money orders, registered letters, or bank checks (preferably on New York banks).

THE

AMERICAN JOURNAL OF SCIENCE

[FOURTH SERIES.]

Art. XLI. — *Experiments on the Reception by Wires of Electric Waves*; by C. A. Chant.

The present paper contains an account of experiments on: (1) the nature of the disturbance about the receiving antenna in the system of wireless telegraphy devised by Braun and Siemens and Halske; (2) the radiation from the Braun, Slaby-Arco and simple Marconi forms of transmitters, observed by the method of resonance; (3) the effect on resonance of inserting a coherer in an open wire; (4) an exploration of wires receiving the radiation from a simple Marconi transmitter; and (5) a repetition of some of Slaby's fundamental experiments.

The paper may be considered as a continuation of a former one* dealing with the transmitting antenna in wireless telegraphy.

A number of investigations have been made on wires arranged as in wireless telegraphy for the reception of electric waves, but in almost every instance these have been restricted to observing a maximum effect at one place,—the base of the antenna,—and as detectors the spark gap, the hot-wire ammeter and the hot-wire thermometer have generally been used.

In my experiments the nature of the oscillatory disturbances was determined by means of the magnetic detector, used in the manner fully described in the former paper, and the exploration extended from one end of the wire to the other.

The wires, both for transmitting and for receiving the waves, were of bare copper, $0{\cdot}7^{mm}$ in diameter, stretched horizontally on the top of wooden posts, about $1{\cdot}5^{m}$ above the floor of the

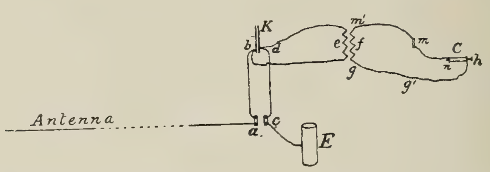
* C. A. Chant, The Variation of Potential along the Transmitting Antenna in Wireless Telegraphy, this Journal (4), vol. xvii, p. 1, 1904. Phil. Mag., (6), vol. vii, p. 124, 1904.

large hall in which the experiments were made. The transmitting wire was about $1{\cdot}5^{m}$ from the wall, the receiving wire being farther out towards the middle of the room.

1. *Exploration of the Receiving Antenna as used in the Braun, Siemens and Halske System of Wireless Telegraphy.*

The apparatus used for these experiments was the experimental set supplied by the Gesellschaft für drahtlose Telegraphie, Berlin, Germany. The transmitter was described in the former paper, and the receiver was arranged as shown in fig. 1. The makers assert that the small set is of exactly the same pattern as their large commercial apparatus.

1



The antenna is connected to a, while to c is joined the earth-plate E, in this case a hollow metal cylinder 20^{cms} long and 8^{cms} in diameter. The receiving transformer is composed of two coils e, f, the former having 5 turns and a diameter of 8^{cms}, the latter, within the former, $5\frac{1}{2}$ turns and a diameter of $7{\cdot}6^{cms}$. At m is a very small condenser, inserted to avoid shunting the coherer C. The ends n, h, are joined to the polarized relay and a dry cell, not shown in the figure. The lengths of the various connections are as follows: ab, 20^{cms}; cd, 20^{cms}; bed, 126^{cms}; $gg'h$, 50^{cms}; $m'mn$, 30^{cms}; coherer, 8^{cms}; coil f, 131^{cms}; hence circuit $ghmfg$ is 219^{cms}.

The receiving antenna was parallel to, and directly opposite, the transmitting antenna, and 2 meters from it. In the first series of experiments the two antennæ were kept equal and both varied from 2 to 10 meters in length. Next, the transmitting antenna was kept 6 meters long and the receiving antenna varied from 2 to 6 meters; and lastly, the transmitting antenna was kept 4 meters long while the receiving one varied from 2 to 6 meters. The readings were taken in regular succession from one end of the wire to the other, usually at points 20^{cms} apart. The results of the examination are shown in Table I and the curves of figures 2 and 3. In the curves, ordinates represent magnetometer deflexions; abscissæ, lengths along the wire, measuring from the free end. Column 2 of the table, giving the position of the minima of the transmitting antenna, is taken from the former paper. It will be

TABLE I.

Transmitting antenna.		Length of receiving antenna and distance, in cms., of minima and maxima from its free end.								
Length.	Position of minima.	1000	900	800	700	600	500	400	300	200
1000	180, (320)	254, 620,* 940								
900	200, (790)		220, 500,* 830							
800	191, (745)			210, 440,* 636						
700	188, (637)				220, 430,* 600					
600	186, (375), (520)					210, 375,* 490	180?	340?	236	150
500	180						312			
400	187, (265)					None	340	300	210	150
300	218								210	
200	..									140

* Maxima.

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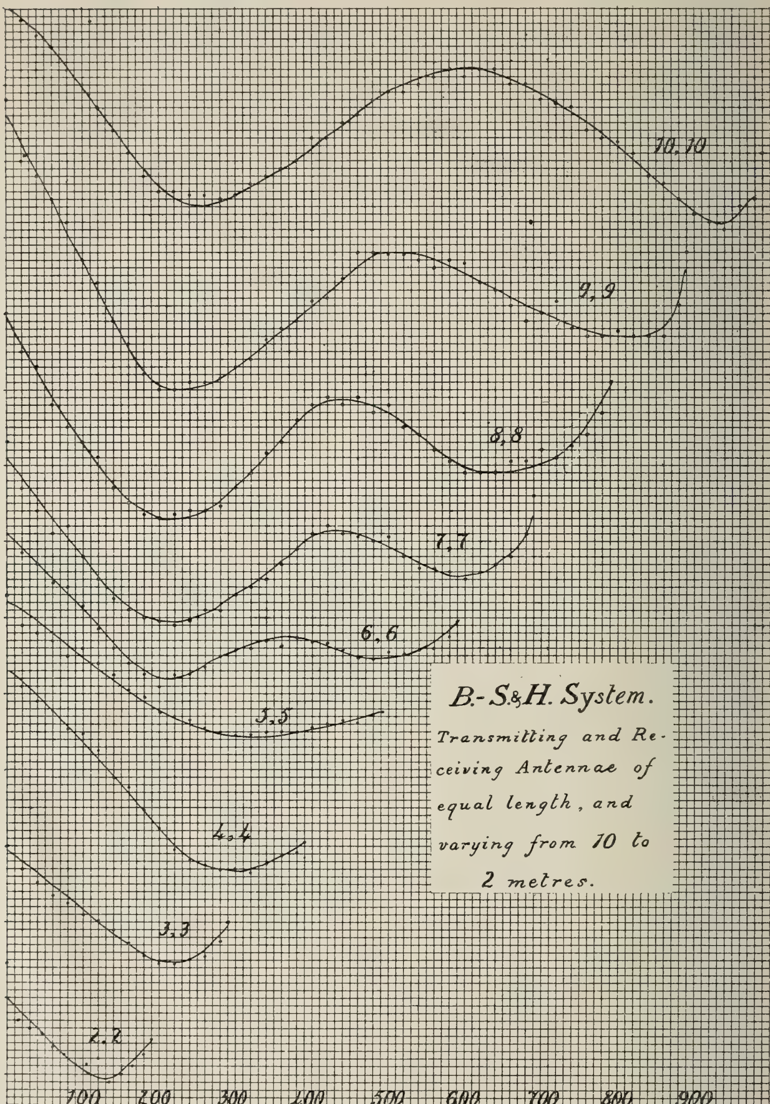

observed that in it there is a minimum at approximately 190$^{\mathrm{cms}}$ from the free end, and this length was interpreted in the former paper as a quarter-wave-length of the condenser circuit.

In the case of the receiving antenna the action appears more complicated. A study of the table and the curves indicates

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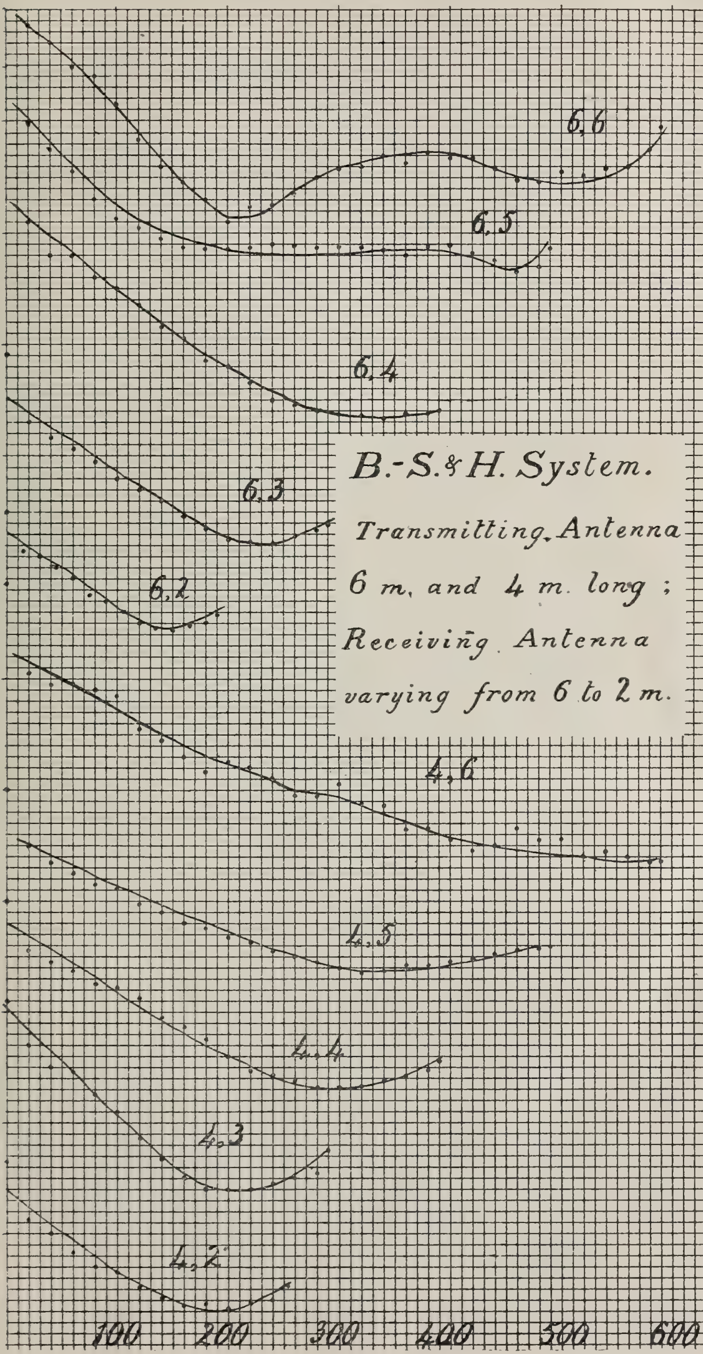
6,6
6,5
6,4
6,3
6,2
B.-S.&H. System.
Transmitting Antenna 6 m. and 4 m. long; Receiving Antenna varying from 6 to 2 m.
4,6
4,5
4,4
4,3
4,2
100
200
300
400
500
600

that there is one law for the wires 6 meters long and upwards, another for those shorter than 6 meters. With the former there is a minimum in the neighborhood of 220^{cms} from the free end. For the wire 1000^{cms} long it appears at 254^{cms} from the end, but this is not so sharply defined as the others, though five sets of readings were taken to obtain this curve while three were usually made for the others.

This appears to be a quarter-wave-length of an oscillation impressed on the wire, but not that shown on the transmitter. Again, if we assume that there is no displacement of the nodes upon reflexion from the free end, the maximum should be found at a distance twice as great from the free end. But such is not the case. There is a distortion of the oscillation, though for what reason it is not evident.

An attempt was made to see what length of the wire was equivalent to the receiver connections, i. e., to the portion from a to E, including E. In doing this the transmitting antenna was 4 meters long, arranged as usual. Opposite and parallel, at a distance of two meters, a wire 4 meters long was stretched, to act as the receiving antenna; and then, in place of the receiving apparatus, a long wire was attached at a and drawn vertically upward, to prevent, if possible, inductive action between this wire and the transmitting antenna. At first this wire was 9 meters long, that is, the entire length of the wire was 13 meters. The horizontal portion only was explored. Then the vertical wire was shortened to 8 meters and the horizontal portion again explored. This process was continued, shortening the vertical wire one meter at a step, until only the horizontal one remained. The results are shown in Table II and the curves of figure 4.

Table II.

Total length of wire in meters.	13	12	11	10	9	8	7	6	5	4
Distance, in cms., of minima from free end.	260	255	225	210	210	207	190, 304	304	253	202
Highest reading, i. e., at free end.	42	51	51	41	28	28	57	92	85	77

An examination of these shows that the wire 6 meters long, i. e., with 2 meters vertical, behaves like the 4-meter antenna when joined to the receiving apparatus, or that this apparatus behaves like 2 meters of wire. This method of substitution is not entirely free from objection, but I know of no better. Somewhat later it will appear from the same method that the cylinder E (fig. 1), is equivalent to about 80^{cms} of the same

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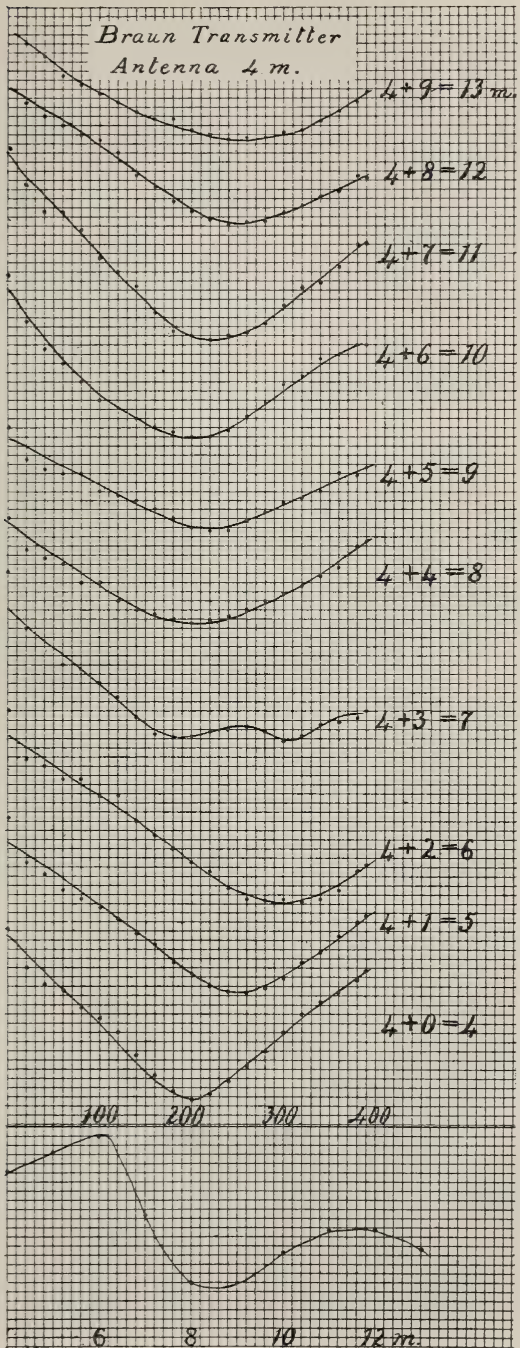
Braun Transmitter
Antenna 4 m.
4+9=13 m.
4+8=12
4+7=11
4+6=10
4+5=9
4+4=8
4+3=7
4+2=6
4+1=5
4+0=4
100
200
300
400
6
8
10
12 m.

wire. If we consider the connection from a to E to be equivalent to 200^{cms}, the above determination would make the condenser equal to 40^{cms} of the wire.

It will be observed in Table II that the minimum for wires of lengths 4, 5 and 6 meters is at the middle of the wire, or the wire is vibrating in its own fundamental mode, while with wires 8 to 11 meters long the minimum is about 210^{cms} from the free end, approximately as in Table I and almost certainly due to the same cause.

This would indicate that in the case of the longer wires the oscillation is forced on the wire, in the case of the shorter the oscillation is that natural to the wires themselves.

2. Examination, by the Method of Resonance, of the Radiation from the Braun, Slaby-Arco and Simple Marconi Transmitters.

In these experiments the transmitter was arranged as usual, and the receiving wire, as in the preceding experiments, was stretched parallel to the transmitting antenna. The action of the incident waves was measured by hanging the detector on the end of the wire. To begin with, the wire was of considerable length, and it was gradually shortened, 10 or 20^{cms} at a time, the effect on the detector hung on the end being observed for each length. As the length of the wire approached that for resonance with the transmitted waves the readings rose, but as the resonant length was passed they fell, until at last the wire was so short that the effect was hardly observable. From the curve obtained by plotting lengths of receiving wire as abscissæ and amount of demagnetization (measured by the magnetometer readings) as ordinates, the length of wire which gave maximum effect was easily determined. This method of determining resonant lengths is extremely simple and easy of application.

The Braun transmitter was the one used in the experiments just described, the antennæ being 3 and 4 meters long. The Slaby-Arco transmitter was that form of Braun's directly-connected system described in the former paper. In the simple Marconi radiator the transmitting antenna was joined immediately to the binding-post forming one terminal of the secondary of the induction coil; the other binding-post was joined directly to earth, while the spark-gap was between knobs 19^{mm} in diameter on the ends of rods passing through the binding-posts. The distance between these posts was 22^{cms}, and the earth-connection was 25^{cms} long, i. e., the distance to earth from the end of the wire attached for antenna was 47^{cms}.

The results obtained are shown in Table III and the curves of figures 5 and 6. The experimental arrangement seems simple and unequivocal, but the conclusions to be drawn are not all so.

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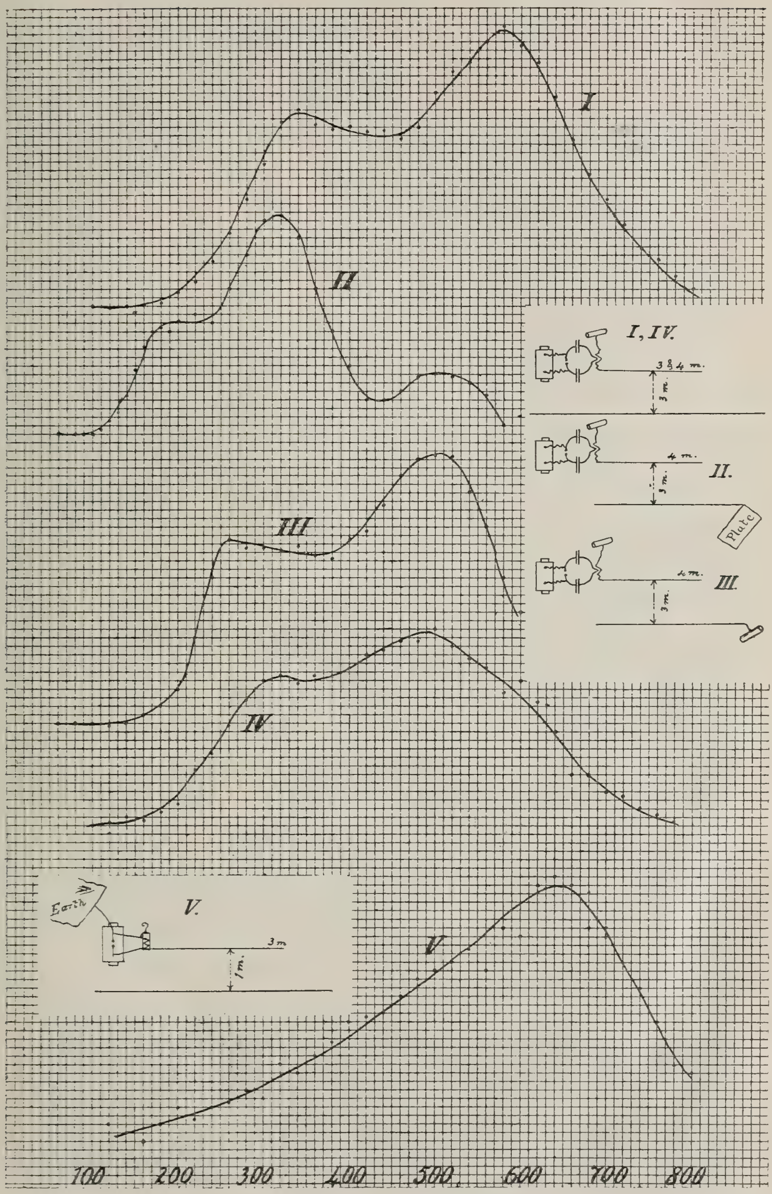

Curve I was obtained with a wire having both ends free, stretched at a distance of 3 meters from the transmitting antenna, which was 4 meters long. There are two definite

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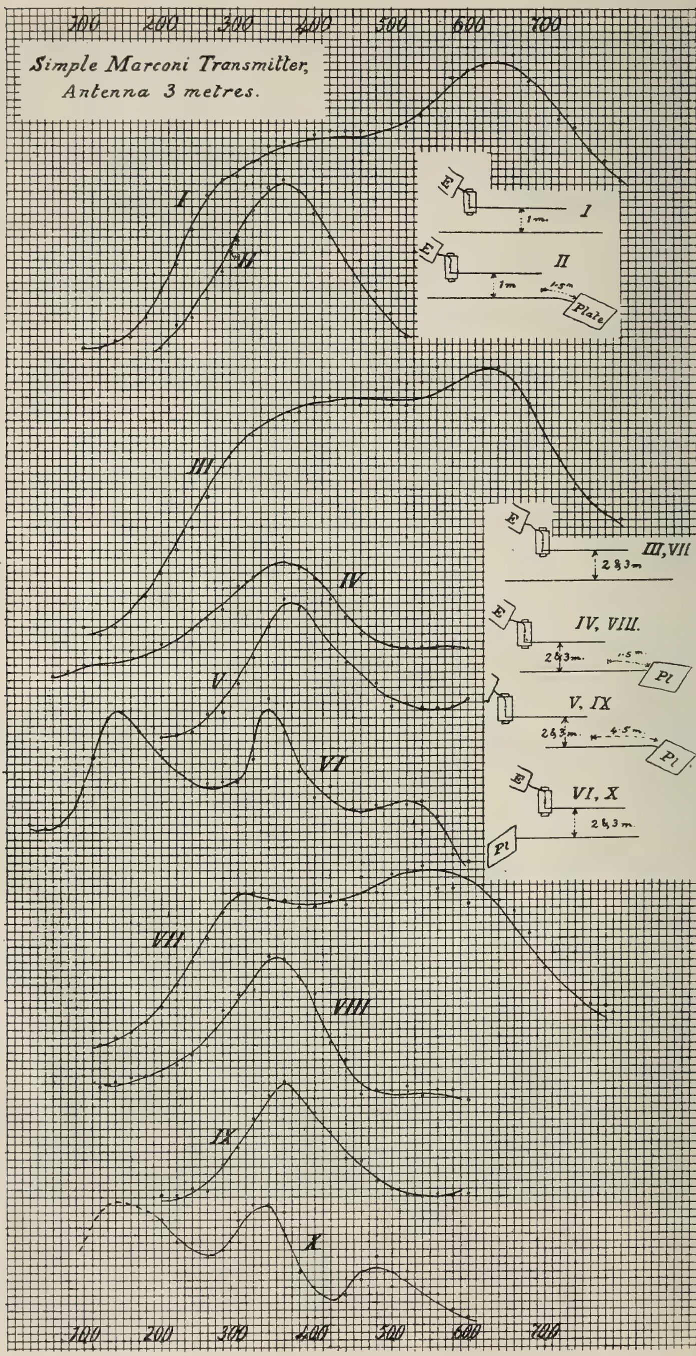

100 200 300 400 500 600 700
Simple Marconi Transmitter,
Antenna 3 metres.
I
II
III
IV
V
VI
VII
VIII
IX
X
E
1m.
1m
Plate
III, VII
2 & 3m
IV, VIII.
Pl
V, IX
4·5m.
VI, X

maxima, showing that wires 335 and 580cms long were in resonance with the radiator, i. e., the radiator emitted waves whose half-wave-lengths were 335 and 580cms, respectively. The latter appears to be the chief one, which fact is indicated in the table by the change in type. The bottom curve in fig. 4 is plotted from the data contained in the lowest line of Table II, ordinates denoting the readings at the end of the wire, abscissæ

TABLE III.

Method of Resonance.

Description of transmitter.	Distance of receiver from transmitter.	Length for maximum reading.	Arrangement of receiving wire.
Braun, 3^m antenna	3 meters	318, *496*, 595	Free wire
" 4 "	"	335, 580 (850,* 1160)	" "
" " "	"	190, *313*, 502	Plate on outer end
" " "	"	*286*, 518	Double plate on outer end
" " "	"	187, *300*, 520	Good earth on outer end
" " "	"	206, *280*, 513	Good earth on inner end
" " "	"	270, *500*	Cylinder on outer end
Simple Marconi, 3^m antenna	1 meter	420, *650*	Free wire
" " "	"	*355*	Plate on outer end
" " "	"	415, *640*	Braun coh'r in free wire
" " "	"	410, *645*	Iron turnings coh'r in free wire
" " "	"	400, *650*	Silver powder coh'r in free wire
" " "	2 meters	400, *620*	Free wire
" " "	"	*360*	Plate at outer end
" " "	"	*365*	" " " "
" " "	"	153, *342*, 533	" " inner "
" " "	3 "	310, 550	Free wire
" " "	"	*348*	Plate at outer end
" " "	"	*360*	" " " "
" " "	"	150?, *336*, 480	" " inner "
Slaby-Arco, 3^m antenna.	1 meter	*638*	Free wire

* Minimum. These two readings are from the bottom curve in fig. 4. The value 580 is found there also.

the length of the wire. The maxima are at 580^{cms} (the value just given), and 1160^{cms} (=580×2), and a minimum at 850^{cms}, half way between.

Next, a large plate of metal, 90 by 180^{cms}, standing in a vertical plane perpendicular to the wire, was securely joined to one end of the wire, which was then examined as before. Here with a capacity so large one would almost expect resonance to take place with wires one-half the previous lengths. But such was not the case, the chief resonance being with a length of 313^{cms}, and less pronounced effects with lengths 190 and 502^{cms} (Curve II). With a plate twice as large, however, the chief resonance was with a wire 286^{cms} long. Next, a good earth was obtained by soldering together metal sheets (total length 6·6 meters, width 80^{cms}) and securely binding one end of the strip so formed to a heating radiator. The maxima are given in the table. When the earth was on the outer end of the wire the chief maximum was given with a length of 300^{cms}, when on the inner end a maximum was given with 280^{cms}. The mean of these two values, 290^{cms}, is exactly half that with the free wire.* This is evidence that on reflection at the free end of a wire there is no loss of phase.

On attaching the small cylindrical capacity supplied with the instrument in place of the large plate, the curve III was obtained, best resonance being given with a wire 500^{cms} long, a smaller effect with 270^{cms}. Curve IV was obtained with the same disposition as for curve I, but with antenna 3 meters long.

It is seen that the cylinder capacity reduces the length of wire from 580 to 500^{cms}, and thus it may be considered, in an oscillating system, as approximately equivalent to 80^{cms} of the wire.

Curve V shows the resonance effect with the Slaby oscillator of antenna 3 meters. It shows resonance for a single half-wave-length of 638^{cms}.

In figure 6 are exhibited resonance effects obtained with the simple Marconi radiator with antenna 3 meters long, the receiving wire being at different distances and arranged in different ways. Curves I and II were taken with the receiving wire 1 meter from the transmitting antenna, III to VI with the distance 2 meters, and VII to X with it 3 meters. Curves I, III, VI refer to a wire free at both ends; II, IV, V, VII, IX with a large plate at the outer end; and VI and X with the plate at the inner end. In every case the plate stood in a plane perpendicular to the wire.

* In the former paper the experiments led to the conclusion that a large capacity (e. g., the earth) joined to a vibrating system acts like a plane mirror in optics, a result first predicted by J. von Geitler, Wied. Ann., lv, p. 313, 1895.

For the wire free at both ends there are two resonant lengths, the resonance not being very sharp, just as we should expect it to be with a radiator much damped. With the plate on the outer end, however, there is only one maximum, which is very clearly marked; while with the plate on the inner end there are three resonant lengths, the chief one being somewhat shorter than with the plate in the former position. From theoretical considerations Wien* concluded that with both the inductively- and the directly-connected radiators there should be present two distinct sets of waves of different periods and damping coefficients. With the Braun apparatus this is clearly evident, but there is no trace of a second maximum with the Slaby radiator. On the other hand, the simple Marconi radiator gives two resonant lengths when the wire is free at both ends, only one, however, with the plate on the outer end, while three are shown when the plate is on the inner end. The reason for this is not easy to see.

Again, the chief resonant length with the plate on the inner end is shorter than with the plate on the outer end. The only reason I can suggest for this is that the presence of the large metal plate alters the frequency of the radiator to some extent, even though it be 2 or 3 meters away. Slaby† found that wires stretched one meter above a zinc-covered floor gave a wave-length ten per cent smaller than when the floor was entirely of wood. He traced this to a variation of the self-induction of the radiator, not of its capacity.

3. *The Effect on Resonance of Inserting a Coherer in an Open Circuit.*

To test for this effect the coherer was inserted in the middle of the straight wire arranged as in I, II, VII, fig. 6, and this then gradually shortened for resonance as before. The simple Marconi radiator with antenna of 3 meters was used and the receiving wire was 1 meter away.

Three coherers were experimented with. The first was the one supplied with the Braun apparatus. The second was of iron turnings in a tube 20^{cms} long and having an internal diameter of 8^{mm}. The third had silver plugs 3^{mm} in diameter, 1^{mm} apart, with about one-fifth of the space between filled with fine powder, mostly of silver. In each case a decohering tapper was arranged on an independent circuit and was kept in continuous action.

* M. Wien, Wied. Ann., lxi, p. 151, 1897; Ann. der Physik, viii, p. 686, 1902; see also G. Seibt. Phys. Zeitschrift, iv, p. 485; Graf Arco, Elektrotechnische Zeitschrift, 1903, p. 1; A. H. Taylor, Physical Review, xviii, p. 230, 1904.

† A. Slaby, Der Multiplikationsstab, ein Wellenmesser fur die Funkentelegraphie, § 7, Elektrotechnische Zeitschrift, No. 50, 1903.

The resonant lengths are given in table 3, but the curves, being quite similar to I, fig. 6, are not shown.

The conclusion was that the coherer did not alter the resonance, that it behaved like its length of good conductor. This agrees with Kiebitz's* results.

4. Exploration of Wires receiving Radiation from the Simple Marconi Transmitter.

In these experiments the antenna was 3 meters long, with the receiving wire (unless otherwise stated) 1 meter distant. The general arrangements are shown in fig. 7.

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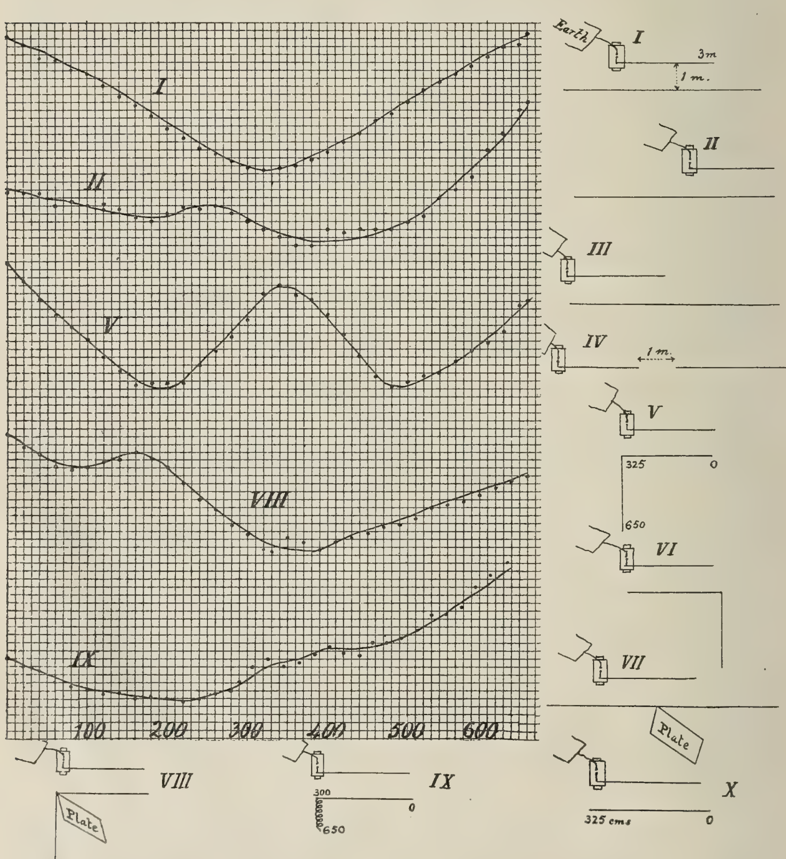

The receiving wire in every case but the last was 650cms long, which length was found in experiments just described (see curve I, fig. 6) to be resonant with the transmitter.

* F. Kiebitz, Ann. der Physik, v, p. 872, 1901; vi, p. 741, 1901.

The exploration showed that with the wire arranged as in I. fig 7, there was present only the fundamental, perfectly formed (see curve I, fig. 7). When the wire was moved along to the position shown in II, the vibration was roughly in the fundamental mode, but very poorly formed, the highest reading being but two-fifths of that in I (see curve II). When, however, the receiving wire was moved along to the position shown in III, the fundamental was well-formed and one-fourth more powerful than in I. This shows that the position of the receiving wire is of importance, the greatest effect being given when the middle of the wire is opposite the end of the antenna. Abraham* has remarked that on account of the transversality of the vibrations, there should be no radiation in the direction of the axis of the antenna. Arrangement IV was to test this conclusion; it was found that the receiving wire responded in a decided manner, a well-formed fundamental being present one-half as powerful as in I. The arrangement V gave the curve shown, the minima being at 180 and 486, the maximum at 352, corresponding roughly to the first harmonic of the wire. The greatest reading was about one-fourth that in I. With a wire bent in the same way but placed as in VI, the fundamental oscillation proper to the wire and as powerful as in I was exhibited. This is a rather striking result. The arrangement VII, with the large metal plate at the center, was indistinguishable from I. That for VIII (the same as V with the plate added at the bend in the wire) gave the fundamental somewhat distorted shown in curve VIII. In IX the coils had a diameter of about $5{\cdot}5^{cms}$, and were 2^{cms} apart. In this case the fundamental was very roughly formed (see curve IX), with the reading at the end of the coil twice as great as at the end of the straight portion. This shows the "multiplication" effect utilized so capably by Slaby and von Arco, though it was not nearly so great as it would have been had the length of the coil been properly adjusted for resonance. In X the wire was half-length, i. e., 325^{cms}, and the fundamental was well-formed, half as powerful as in I.

5. *Repetition of some of Slaby's Fundamental Experiments.*

The methods here used for determining resonant lengths and for exploring the wires seemed well suited for repeating some of Slaby's† fundamental experiments, and my results in some cases were somewhat different from those published.

Each half of the oscillator consisted of a brass rod $3{\cdot}4^{mm}$ in

*M. Abraham, Ann. der Physik, ii, p. 32, 1900.

†A. Slaby, The Scientific Basis of Spark Telegraphy, Elektrotechnische Zeitschrift, No. 9, 1902; Lond. Electrician, vol. xlix, p. 6, 1902. Also, Der Multiplikationsstab, etc., Elektrotechnische Zeitschrift, No. 50, 1903.

diameter, ending in a knob $9\cdot5^{\text{mm}}$ in diameter, the length over all being 1 meter. The spark-length was $2\cdot8^{\text{mm}}$ in air, and the knobs were kept polished for good effects.

First, the length of wire required for resonance with the oscillator was found as explained in section 2. The experimental

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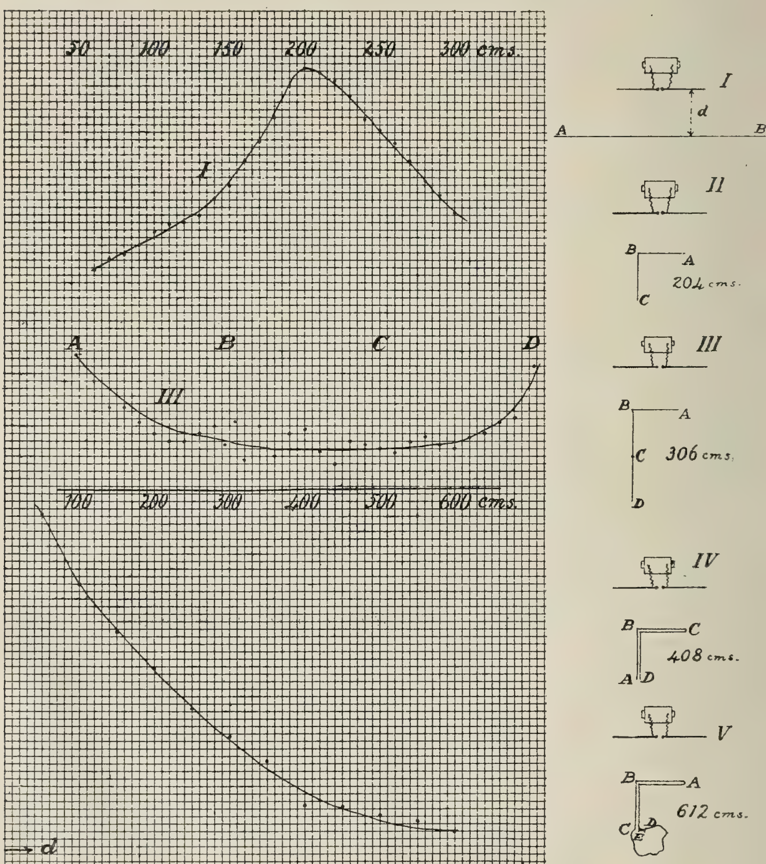

disposition is shown in diagram I of figure 8, distance *d* being 1 meter, and curve I shows the result. Resonance was well-marked, attaining a maximum with a length 204^{cms}. This is evidently the half-wave-length of the oscillator. Then the wire AB was made in succession 204^{cms} and 102^{cms} long, and at a distance, *d*, of 1 meter, was explored when exposed to the action of the oscillator. In each case there was a well-marked fundamental.

With the wires 204^{cms} long, bent at the middle and placed as in II, the oscillation was the fundamental proper to the wire with node at B. When a wire 306^{cms} long was bent and placed as in III, the effect was weak and the vibration poorly formed, as shown in the corresponding curve. There is a loop of potential at each free end, and no other pronounced feature. With 408^{cms} of wire doubled and bent as in IV, the vibration was perfectly formed with nodes at B,D, loops at A,C,E.

Next, a wire 612^{cms} long, the straight portions being the same as in IV, and the bent portion CD being 204^{cms} long, was examined, first with a Braun coherer between the ends D,E, and secondly with the ends D,E joined directly. The effect on this closed circuit was small, with no trace of nodes or loops to be found.

Then a wire 280^{cms} long, arranged as in I, was explored. Here the wire was much out of resonance. The vibration was the fundamental proper to the wire and very well formed.

Lastly, the relation between the magnitude of the effect and the distance of the resonating wire from the oscillator was determined. For this the wire was 204^{cms} long, and the distance d was varied from 50 to 600^{cms}. In the accompanying curve abscissæ give the distance d, the ordinates the corresponding demagnetization of the detector hung on the end of the wire. It will be seen that the curve is hyperbolic in form, and the effect, therefore, varies inversely as the distance.

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ART. XLII.—*Spectra of Gases at High Temperatures;* by JOHN TROWBRIDGE.

[Presented at the International Electrical Congress of St. Louis, 1904.]

THE new theories in regard to the complexity of the atom, together with a multiplicity of ionization phenomena, make the results of spectrum analysis obtained by the discharges of electricity in glass or quartz tubes difficult of interpretation. To use ordinary language, "so many things can happen," such as dissociation; combination with the gases set free from the walls of the containing tubes; masking of the spectrum of one gas by that of another, reversals of spectrum lines and so on.

These complicated conditions which accompany our study of gaseous spectra make it almost impossible to conclude from laboratory experiments that we have imitated the phenomena presented by the distant stars.

For several years I have been endeavoring to obtain new series of hydrogen lines which might presumably manifest themselves at very high temperatures. In the progress of this work I have obtained a number of interesting facts which I shall dwell upon in a brief manner in this paper; but I have failed to find a new series of hydrogen lines, possibly from the reason that the reactions both in glass and quartz vessels mask the series. It seems impossible to experiment at a higher temperature than I have obtained, certainly if one employs such vessels as I have mentioned.

My investigations have been conducted with a storage battery of 20,000 cells, which were used to charge large condensers. The advantages in using a storage battery for experiments in spectrum analysis are well recognized. These advantages are especially seen in the employment of condenser discharges. When the condensers are charged through a large liquid resistance they charge to the same potential each time, and then discharge without the intervention of a discharger, through the Geissler tube. The number of discharges can be closely regulated by the amount of liquid resistance which connects the poles of the condensers to the battery. The regularity of such discharges through the Geissler tubes is remarkable. In popular language one can call the arrangement an electric clock, for the discharges follow each other at regular intervals. In this way one avoids the spark at a discharger and is sure of always obtaining the same difference of potential at the ends of the Geissler tube.

The highest temperature to which one can submit a gas is presumably that of the electric discharge from a condenser; opinions differ in regard to the degree of heat which one can

obtain by such a discharge. The limit I have reached is the volatilization of silica; perhaps 1800 degrees. At this temperature the spectrum shown by all gases in narrow capillary tubes consists of a continuous spectrum crossed by broad bands due to silica or to an oxide of silica; the gaseous spectra are completely masked. This masking seems to be due to the greater conductibility of the volatilization products from the walls of the tubes and from the metallic terminals. It seems to me that this variation in conductibility is sufficient to account for the phenomena of masking without recourse to a theory of electrons which provides for suitable damping of electrical oscillations. The electron theory may be an ultimate explanation, however, of electrical conduction.

When terminals of different metals are employed in capillary tubes of glass or quartz, and are separated four or five millimeters, complicated phenomena result from powerful condenser discharges through the rarified gases contained in these tubes.

All specimens of glass which I have tried, soft German glass, lead glass, Borsilicon glass, or Jena glass, give broad bands due to silica; lead glass gives, in addition, lead lines. Jena glass gives a very strong line of boron at wave length 3451·49. These lines and bands are obscured by a continuous spectrum.

The narrow capillaries with metallic terminals, which I have used, may be called electric furnaces in which there is no permanent product or permanent decomposition; moreover, the spectra which we observe do not reveal all that the capillaries contain. Hydrogen may be present; but it is concealed. Oxygen shows its presence only by probable oxides; the constituents of rarified air are undoubtedly always there. The conditions which prevail in the case of discharges in such narrow capillaries seem to be analogous to those in the case of discharges under liquids. In this latter case we also have reversals of metallic lines; and, moreover, certain characteristic lines of metals are wanting—see "Spectra from the Wehnelt Interrupter," Harry W. Morse. (Proc. American Academy of Sciences, May, 1904.)

These results make one doubtful in regard to the entire subject of spark spectra which are observed between metallic terminals in ordinary air; and we are forced to ask, what influence does the environment have upon the character of these spectra—to what must we attribute the presence of oxygen? And even if we take spark spectra between metallic terminals in an atmosphere of hydrogen or nitrogen we are not sure that the results are not modified by the gases which are occluded in the metallic terminals.

Are we sure that, even in electrodeless tubes, helium is a

product of disintegration of radium; a transmutation, so to speak; and is not a result of the electrical stimulus in the environment of glass or quartz a stimulus which may bring to light the helium which has refused to manifest itself by chemical analysis?

In general it may be said that the greater the conductibility of the volatilization, products either from the walls of the tubes or from the metallic terminals determine the occurrence of the spectral lines or bands. The spectrum, for instance, of silica completely masks the spectrum of the iron terminals when the latter are placed not more than five millimeters apart. When the terminals are of different metals the spectrum of the more volatilizable metal predominates: or more strictly, the spectrum of the better conducting vapor.

Another striking fact brought to light by such discharges in capillaries is the reversal of many of the spectral lines on broad bands. The broadening of the lines of the metals is generally toward the red end of the spectrnm. The quantity of the discharge appears to be the important factor in determining the character of the spectra; electromotive force, *per se*, does not give new lines which can be detected by photography. The effect of high electromotive force begins to be evident at high exhaustions and then only in producing cathode and X-rays.

This latter fact can be well shown by a Tesla coil actuated by a Cooper-Hewitt mercury interrupter such as was employed by Dr. G. W. Pierce (Proc. Am. Acad., 1904). With a suitable step-up transformer, in connection with such an interrupter, I have studied the spectrum of hydrogen, and have not obtained a spectrum which differed from the one obtained by the same amount of energy with a lower voltage. The high voltage ranged from 100,000 volts to 3,000,000.

The broadening of metallic lines seems to indicate an oxidization. One can conceive of a loading of the metallic molecule by various degrees of oxidization which leads to a broadening towards the red end of the spectrum, or in other words to longer wave lengths, and an unloading due to dissociation which leaves the molecule free to emit shorter wave lengths. That an oxidization results from a discharge of electricity in glass or quartz tubes filled even with apparently dry hydrogen seems to me to be evident from my experiments. The unavoidable presence of water-vapor in glass, and I may add, in quartz tubes, lends color to this oxidization theory; this vapor is dissociated by the electric current, the oxygen, set free, combines with the molecules of the metals, or with the molecules of silica and its metallic impurities.

The following experiment illustrates this oxidization:

A Geissler tube, fig. 1, with an internal diameter of one inch, was provided with an inner capillary, one end of which was blown to the walls of the larger tube; the other end was free inside this larger tube. An electric discharge passed between two ring electrodes A and B, which were placed in the larger tube. The discharge, therefore, started, so to speak, in the larger tube, passed through the narrow channel of the capillary and emerged to the cathode. The tube was filled with pure hydrogen which was dried by phosphoric pentoxide. Under the effect of powerful condenser discharges, the four-line spectrum was much enfeebled in the capillary; the red color, characteristic of condenser discharges in hydrogen, gave place to a brilliant white light, and when the capillary was viewed end on, a continuous spectrum was seen. When, however, the discharge issued from the capillary a brilliant red aureole was seen around the end of the capillary. This aureole gave a much enhanced four-line spectrum. The temperature inside the capillary was sufficient to volatilize the walls of the capillary, and, therefore, was competent to decompose the water-vapor into oxygen and hydrogen. Just outside the end of the capillary, the temperature fell to the point of recombination of these gases to water-vapor.

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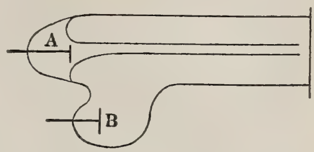

In another experiment the Geissler tube G, fig. 2, was placed between two manometer gauges, and was exhausted to such a degree that the electric discharge failed to pass. One end of the Geissler tube, that nearest to the pump, was shut off by

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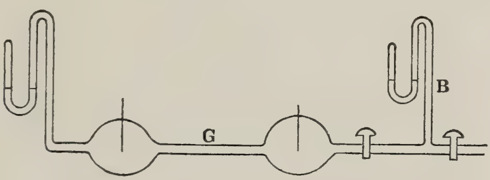

means of a stopcock B; and dry oxygen was admitted to the pump until the manometer gauge connected with the pump indicated two centimeters pressure. The stopcock was then opened so as to admit the gas to the Geissler tube. The corresponding manometer gauge at the opposite end of the Geissler failed to register the requisite equalization of pressure, there having arisen an oxidization of the mercury meniscus by means of which the capillary constant between it and the glass

had been changed. This holding of the mercury meniscus was large and had to be overcome by vigorous tapping of the tube. An analogous effect was obtained when the Geissler tube was filled with rarified air, and also when it was filled with nitrogen. When, however, it was filled with dry hydrogen, the holding effect was comparatively inappreciable. The oxygen produced by the dissociative effect of the electric discharge combined with the hydrogen and no longer oxidized the surface of the mercury. In this connection it may be observed that the mercury meniscus in the Lippman electrometer is affected principally when it is made the positive pole, and, therefore, oxygen is liberated.

Perhaps the most striking experiment in this connection can be made with the steady current from a large storage battery. When Geissler tubes, preferably of half a centimeter internal diameter, are provided with copper terminals, and are filled with dry hydrogen at pressures of one millimeter to one-tenth of a millimeter, a steady diminution in the pressure of the gas results from the application of the discharge; the light of the spectrum grows dimmer and dimmer, then the cathode rays appear, finally the X-rays, and then no discharge can be forced through the tube until a much higher electromotive force is employed, or heat is applied to the tube. This heat evidently drives off water-vapor from the walls of the tube together with air; a fresh application of the steady current again diminishes the pressure in the tube to an apparent vacuum. Thus one can exhaust, so to speak, a Geissler tube by employing a steady current of electricity to dissociate the ever present water-vapor. With copper electrodes, the oxidization produced by this dissociation is more evident than with the other metals; although I have observed it with magnesium terminals, with iron terminals and with other metals.

These experiments lead me to believe that, just as in chemical reactions, a certain amount of water-vapor or humidity is essential to conduction in gases whether brought about by what is called chemical affinity or electrolytic action.

I have dwelt upon the broadening of the lines of metals in capillary tubes. This phenomenon is also observed with hydrogen lines, and was first noticed by Liveing and Dewar, Chem. News, xlvii, p. 122, 1883. These authors attributed the broadening to compression of the gas in the narrow capillary under the effect of a powerful condenser discharge. Their method of experiment was as follows: The tube was exhausted only to perhaps five or six centimeters pressure, so that a white discharge of a spark nature passed through the capillary and then spread out to electrodes placed in the large ends of the tube. When the tube was viewed end-on, a continuous spec-

trum was seen in the capillary; moreover, this continuous spectrum was crossed by a dark line which resulted from the absorption of heat in the colder layers of gas in the larger portions of the tube.

The broadening of the spectra of the vapors of metals which I have observed in capillary tubes has thus its analogy in the case of gaseous spectra.

Having obtained reversals of the spectra of metallic vapors under new conditions, I was naturally interested in the experiment of Liveing and Dewar, especially since a controversy had arisen between M. Cantor and E. Pringsheim in regard to the possibility of the reversal of gaseous lines in Geissler tubes. M. Cantor* concluded from his experiments that such reversals do not occur in the phenomena of luminescence, such as one obtains by the discharges of electricity in Geissler tubes. Pringsheim objected to these conclusions on the ground that Cantor did not observe a sufficiently narrow portion of the spectrum of the gas and did not use sufficient dispersion. Pringsheim† quotes the results of Liveing and Dewar in support of his position.

In repeating Liveing and Dewar's experiment, it occurred to me that objection might be brought against it on the ground that it was a spark discharge and not a clearly marked glow or luminiscent discharge such as Cantor evidently had in mind. I, therefore, placed a second spark gap (fig. 3, S) just outside the inner capillary of the large Geissler tube provided with an

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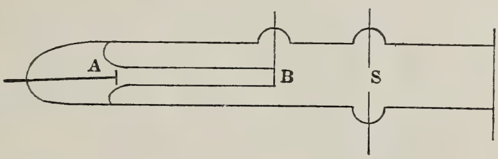

inner capillary, as I have previously described in speaking of the temperature inside a capillary and in the space just outside. The discharge passed first through the capillary and then by means of an outside connection through the second spark gap; thus the light from the capillary passed through the light from the second spark gap. In both cases the light was a glow or luminescence and not a white spark discharge, the pressure in the tube being from one to two centimeters.

A Rowland grating was employed and an eye-piece was fixed on the C line of hydrogen. The second spark gap gave a fine bright line of the apparent length of the slit, the capil-

* Ann. der Phys., 3, 462, 1900.
† Ann. der Phys., 5, 1900.

lary a continuous spectrum, and where the fine bright line crossed this continuous spectrum, it was reversed.

Kirchhoff's law of radiation thus applies to the radiation in Geissler tubes, and Pringsheim's contention is justified. If the solar corona is an electrical phenomenon of the nature of luminescence, it can exhibit either bright lines or dark lines according as it is hotter or colder than the background.

In this study of the upper limit of temperature which one can reach by electric discharges through rarified gases, we perceive that spectrum analysis is one of the most difficult analyses which modern science has revealed. There are a few broad facts such as Doppler's principle and the reversal of spectral lines according to Kirchhoff's law; on the other hand, there is ionization, dissociation, adsorption and absorption, all modified by the glass or quartz vessels which must be employed.

M. Cantor calls attention to the fact that Hittorf failed also to observe reversals of spectral lines in the case of electric discharges in Geissler tubes. Hittorf speaks of a first series of hydrogen lines which are seen with feeble discharges. This feeble spectrum with its bands seems to be a peculiarly luminescent effect in which any translatory or colliding effect of the molecules is a minimum. The new theories in regard to the composite nature of the atom seem to demand an extension of our views in regard to the nature of the light emitted by atoms and their aggregates under the stimulus of an electric discharge. The phosphoreseent and fluorescent light of a gas under this stimulus may arise from the mechanism of the atom and therefore may not give sensible heat. The combination of atoms into molecules, and their dissociation and formation of new combinations, may give the spectra we usually observe under the effect of fairly strong electric discharges, and provide the sensible heat which can be measured by the bolometer or the thermal junction.

Spectrum analysis of the future thus becomes more and more difficult of application, and one of its most important fields is in the study of phosphorescent and fluorescent light emitted by gases. We seem to be on the point of regarding the light and heat of the sun more from the electrical standpoint. And the study of discharges of electricity in rarified gases assumes a great importance.

ART. XLIII.—*Two New River Reptiles from the Titanothere Beds;* by F. B. LOOMIS.

ALTHOUGH the Titanothere beds of the White River formation are usually regarded as of flood plain origin, the known distinctively river animals are very few. Such forms as Elotherium and Cænopus lived along the river banks; but of those dwelling in the water itself, none has been described, although occasionally a reference is made to fragments of Trionyx. The Amherst College Expedition of 1903 found two well-preserved river forms, which, together with a remarkable case of redeposition of Cretaceous fossils in the White River beds, make the basis of this paper.

Several times in the Oligocene "Bad Lands" along the Cheyenne River fragments of crocodilian dermal scutes were found; and, finally, in the Finney Breaks near Fulsom Post Office, S. D., a specimen came to light, consisting of 10 vertebræ, 25 dermal scutes, the femur, tibia, astragulus and a number of fragments. Then, in the museum of the South Dakota School of Mines, Prof. O'Hara showed me a crocodilian snout, found in the Titanothere beds in Indian Draw, distant some six miles from the first specimen. This imperfect skull is used as the type of the new species; and the skeletal parts, inasmuch as they are of dimensions appropriate to the skull, are referred to the same species, of which the following is the description.

Crocodilus prenasalis, nov. spec. Figs. 1–9; 1–6, $\times \frac{1}{2}$, 7–9, $\times \frac{1}{1}$.

The front end of the cranium with nine tooth alveoli on either side is preserved, together with the anterior part of the lower jaw, still in position. The snout is broad and short, indicating a wide head. The undivided nasal opening is very far forward, and differs from that of other crocodiles in the lack of a distinct anterior border, this portion of the nasal cavity having a smooth, rimless boundary on the præmaxilla. The nostril opening would seem, therefore, to have been directed to the front rather than upward on top of the snout. (This lack of a rim gives the snout a distinctly mammalian appearance.) The boundaries of the frontals are not distinct, but if what appears to be the suture is correct, they are unusually wide. Their upper surface is covered with good-sized pits. On the left side, just where the snout is broken off, is a constriction on the maxilla to receive a tooth of the lower jaw. This comes just behind the ninth superior tooth, but just which tooth of the lower jaw would fit into it cannot be determined, as the two jaws are closely interlocked. The two halves of the lower jaw are completely fused at the symphysis.

The teeth preserved (the eighth and fourth superiors on the left side) are conical, slender and slightly recurved.

The vertebræ are all deeply procœlous. Those of the lumbar region have heads (posterior), which are short, wider than high and rectangular in outline. Those of the dorsal region, however, are smaller and have prominent conical, rounded heads.

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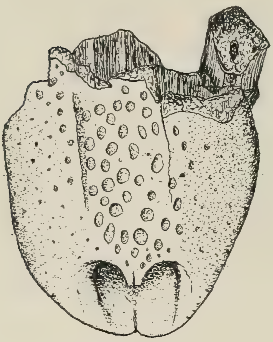

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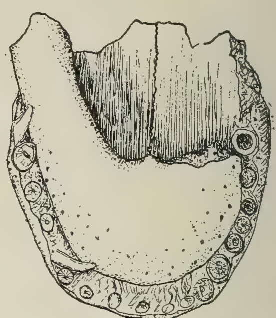

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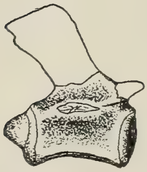

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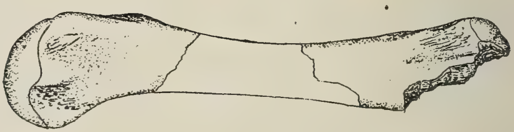

The dermal scutes are of many shapes, mostly quadrilateral. Some have sutures on both lateral margins and seem to have been in rows up and down the back. I should judge there were four rows. Some have the suture along one side only, and must have belonged to the outside rows. And lastly, a few seem to have lain free in the flesh, having no trace of a contact. Types of each sort are figured (figs. 7–9, $\times\frac{1}{1}$). All are deeply and profusely pitted. Those which were in the rows have a more or less marked ridge running lengthwise.

The femur has a wide flattened head, the articulation extending around the whole end as in the modern forms. The tibia is very like that of a living *C. palustris*, as is also the astragulus, which, however, has a shorter heel.

7

8

9

For measurements see the figures, which are all to scale.

Chrysemys inornata, nov. spec. Figs. 10, 11. $\times\frac{2}{5}$.

The genus Chrysemys, to which Hay* ascribes many of the Eocene species described as Emys, has not been heretofore found in the Oligocene, although to be expected in river deposits. A good many small undeterminable fragments were picked up through the summer; and finally, while excavating a titanotherium skeleton at the head of Bear Creek in Spring Draw Basin—ten miles east of Creston Post Office,—directly under the skull, as though crushed by the fall of that animal, was discovered a complete carapace and plastron of *C. inornata.*

The carapace is broadly oval and but moderately convex. The anterior margin has a shallow median notch: the posterior a distinct median notch, and on either side three diminishing scallops, one on each marginal plate. The nuchal plate is much wider than long; so that its lateral corners underlie the first costal scute on either side. The antero-lateral borders of vertebral plates numbers 1 to 6 are much shorter than the postero-lateral borders. The anterior sulcus of dorsal scute number 5 crosses the anterior end of neural plate No. 9. In general appearance this species closely resembles *Emys latitvertebralis* Cope† from the Wasatch: but on *C. inornata* the posterior margin is scalloped (resembling *C. scripta* in this respect). Then in *E. lativertebralis* the nuchal plate does not extend under the first costal scute. Lastly, the tenth neural plate of *C. inornata* is longer than that of *E. lativertebralis*, while the eighth is shorter.

The plastron is about two-thirds the width of the carapace, the meso-sternal plate being anterior to the pectero-humeral suture. This plate is as wide as long and broadly rounded.

*Bull. U. S. Geol. Surv., No. 179, p. 447. This Journal (4), xviii, 267, 1904. † Geog. Surv. West of 100 Meridian, vol. iv, p. 53.

The posterior lobes of the plastron end in broad points, due to the inner margin of the anal plates being deeply excavated.

The shell throughout is thin, the sutures being strongly marked.

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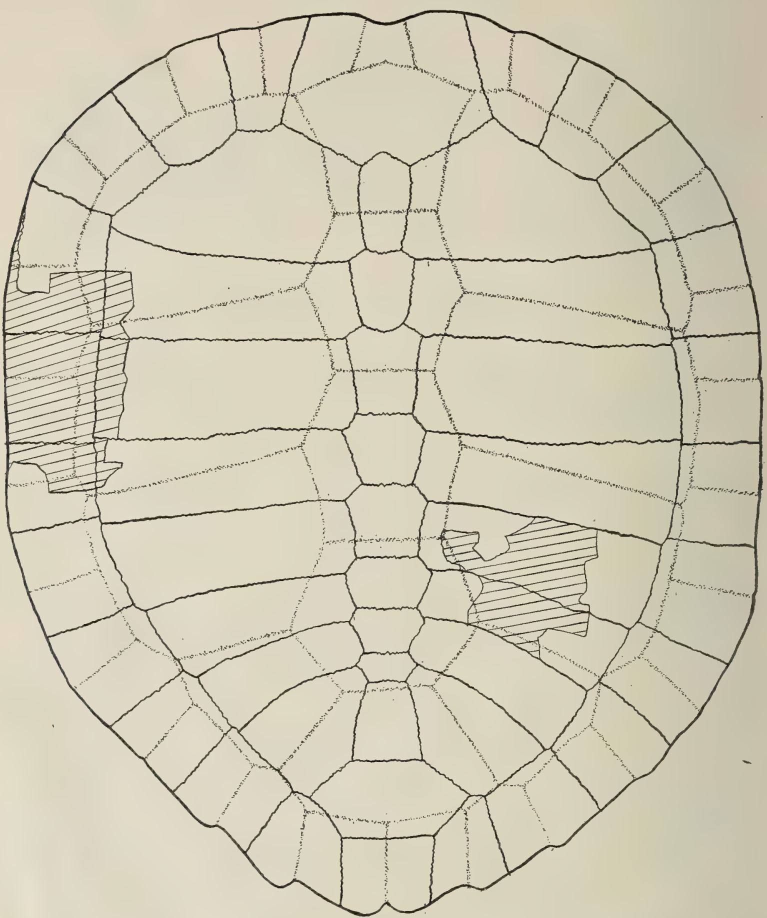

The following are the most important measurements, all parts of the drawings being to scale.

Length of carapace	·303 meters
Width of carapace	·253
Length of plastron	·265
Width of plastron	·144
Length of meso-sternum	·045
Width of meso-sternum	·045

Along with these fossils was an unusual bit of evidence of the river origin of the Titanothere beds, supplementary to that already given by Matthew* and others. On the head of Bear Creek and along the north side of Spring Draw Basin, about thirty feet above the undoubted base of the White River beds,

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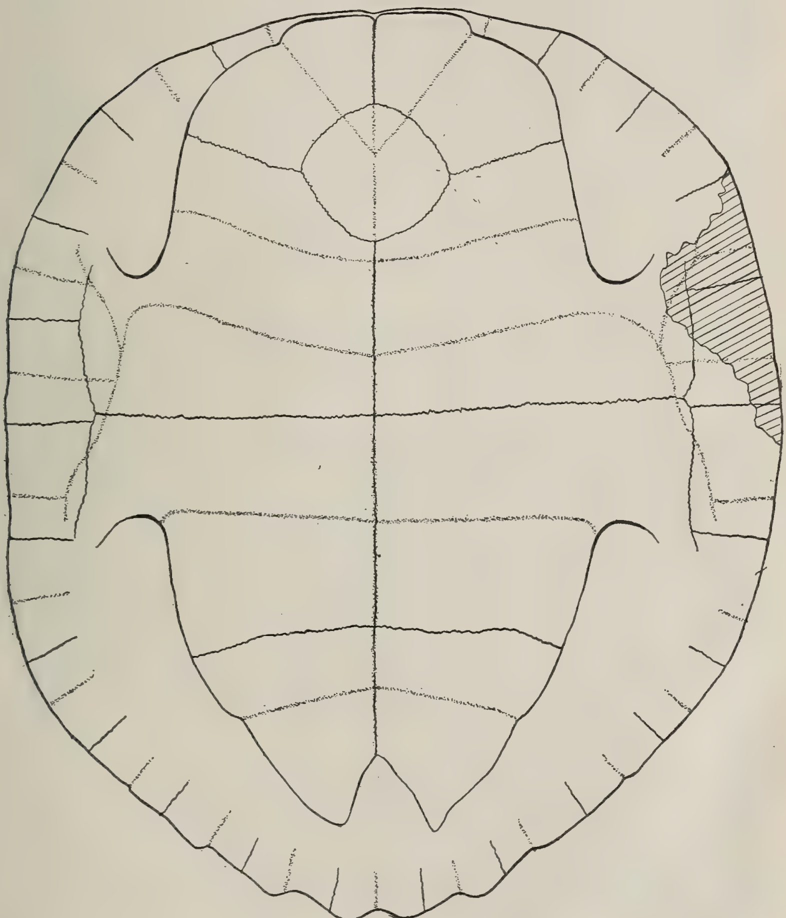


was found a considerable collection of Ft. Pierre fossils. The collection consists of 15 *Baculites ovatus* S., 2 *Baculites grandis* H. & M. Over 100 baculites were seen, but only such as had satisfactory sutures were saved, and a specimen of a Mosasaur

* Matthew, Amer. Nat., vol. xxxiii, 1899, p. 403; Davis, Proc. Amer. Acad. Arts and Sciences, vol. xxxv, 1900, p. 345.

(Platycarpus ?) consisting of 20 vertebræ, $2\frac{1}{2}$ paddle pieces and some fragments, 28 bones in all. All of these occurred in concretions similar in shape, size and structure to those in the Ft. Pierre but lighter in color, and stained with hæmatite on the outside and wherever weathered. The baculites occurred over an area about three miles in diameter, in many places in great abundance. However, in none of the neighboring localities did any trace of these fossils occur; although the Titanothere beds were carefully examined for more such material. The species are those not uncommon in the neighboring Ft. Pierre. The underlying Oligocene is mostly the typical white chalk of the formation, with near the base some beds of sand and gravel. In the chalky beds about six feet above the base of the White River formation, and 25 feet below the Ft. Pierre fossils, Titanotherium bones were collected. The beds are clearly Oligocene: the fossils clearly Cretaceous.

But one explanation is at all adequate, and that is, that the river depositing the Titanothere beds supplemented the load of mud its waters were carrying by washing out the Ft. Pierre of its banks, and carried this along, depositing it with the rest. The distance probably was not great. The current must have been rapid however; for the concretions were carried with the fossils. This is certain, for the baculites would never stand transportation without breaking, except in the concretions. Then 28 bones of a Mosasaur were not excavated, carried along and redeposited together, unless held by a matrix. The size of the concretions is from one to three feet in diameter, indicating what the force of the current must have been. Inasmuch as the nature of the material making up the Titanothere beds, and the contained fauna, have already been considered sufficient evidence for the river origin of these beds, such a case of redeposition seems to me conclusive evidence of the flood plain formation of the beds. And the foregoing has given two at least of the forms living in the river.

EXPLANATION OF FIGURES.

FIG. 1.—*Crocodilus prenasalis* nov. spec., snout of specimen No. 1 seen from above. $\times \frac{1}{2}$.
FIG. 2.—Same seen from below. $\times \frac{1}{2}$.
FIG. 3.—*Crocodilus prenasalis* nov. spec., specimen No. 2 dorsal vertebra. $\times \frac{1}{2}$.
FIG. 4.—Tibia of same. $\times \frac{1}{2}$.
FIG. 5.—Femur of same. $\times \frac{1}{2}$.
FIG. 6.—Astragalus of same. $\times \frac{1}{2}$.
FIG. 7.—Dermal scute with two margins sutured. $\times \frac{1}{1}$.
FIG. 8.—Dermal scute with one margin sutured. $\times \frac{1}{1}$.
FIG. 9.—Dermal scute which lay free in the skin. $\times \frac{1}{1}$.
FIG. 10.—*Chrysemys inornata* nov. spec., carapace. $\times \frac{2}{5}$.
FIG. 11.— " " " " plastron. $\times \frac{2}{5}$.

ART. XLIV.—*Emmonsite* (?) *from a New Locality* ; by W. F. HILLEBRAND.

DR. WALDEMAR LINDGREN, of the Geological Survey, collected in the W. P. H. mine at Cripple Creek, Colorado, a green mineral which has been observed in other mines there, and which on examination in the laboratory showed close resemblances to the emmonsite described by the writer nearly twenty years ago.* It differed from it, however, in outward appearance by assuming mammillary forms instead of crystalline plates. In its optical properties, so far as they were determinable, there is perhaps no positive disagreement with those reported for emmonsite. Mr. W.T. Schaller reports as follows :

"There are two cleavages, one parallel to *b* (010) and another parallel to a form in the orthozone. Axial plane parallel to *b* (010). Bx_a perpendicular to a cleavage face in the orthozone. The extinction on the clinopinacoid is inclined 25° to 30° to the vertical axis. 2E is approximately 40°. Double refraction medium, and the mineral non-pleochroic."

The gangue in which the specimens were found is granite and schist, close to their contact with a porphyritic breccia, in a vein pocket, at a distance of about 150 feet from the surface. Associated with it was very rich native gold ore and also tellurite, though neither of these was apparent on the few specimens that came to the laboratory.

Like emmonsite, the mineral melts at a low heat to a red-brown liquid, but, unlike it, gives on stronger heating only tellurous oxide with no trace of selenium or selenious oxide. Analysis confirmed the absence of selenium. Its density, too, differs from that of emmonsite, if the determinations, in both cases on scanty material, are to be depended on. After allowing for gangue the original emmonsite was judged to have a density of at least 5, while that of the present mineral is but little above 4·53, after allowing for 22·44 per cent of gangue, consisting mainly of quartz, and to which the specific gravity of quartz was assigned.

In its appearance the present mineral would seem to resemble durdenite more than emmonsite, but the marked difference in water content differentiates it sharply from that mineral, which yields over ten per cent.

After deducting 22·44 per cent of gangue containing over 90 per cent of silica, three portions of from 0·15 to 0·20 gram net weight each gave the following results :

* Proc. Colorado Sci. Soc., ii, 20, 1885.

				Mean.	Ratios.
TeO_2	70·83	71·80	70·20	70·71	3·16
Fe_2O_3	22·67	22·81	22·79	22·76	1·00
H_2O at 100°	4·68	4·82	0·21	0·21	
H_2O above 100°				4·54	1·77
P_2O_5	0·34			0·34	
Al_2O_3		0·58	0·54	0·56	
SiO_2, etc.*				0·88	
				100·00	

Allowing alumina to offset the P_2O_5, though it may belong to a soluble silicate or to the tellurite and a small proportion of iron be demanded for the P_2O_5, the ratios given in the final column result. They are as unsatisfactory as those afforded by the original emmonsite, which were for Fe_2O_3: TeO_2, 1 : 3·65 in the original description and 1 : 3·75 : 1·82 for $Fe_2O_3 : TeO_2 : H_2O$ if the supplementary determinations in this Journal, xl, 81, 1899, are accepted. The presence of tellurite in association with the green mineral suggests a possible explanation of the failure to obtain a simple ratio, though such contamination was not noted in the material analyzed nor on the neighboring gangue. If this explanation is correct, however, the variation from the original emmonsite ratio becomes still more marked. Provisionally the mineral may be regarded as emmonsite.

The above results are given in some detail, notwithstanding their inconclusiveness, because of the importance of accumulating data regarding the as yet small but interesting group of ferric tellurites, and inciting collectors and mining men to careful search for and preservation of further material for more extended study.

Thus far, emmonsite, durdenite, and an unnamed mineral from Cripple Creek, described by Knight in the Proc. Colorado Sci. Soc., v, 66, and affording likewise unsatisfactory ratios, comprise the list of natural ferric tellurites, the formula of no one of which can be regarded as established beyond question.

U. S. Geological Survey, Washington, D. C., Oct. 1904.

* Includes alkalies, traces of magnesia and gold, and a small amount of a metal or metals precipitable by hydrogen sulphide, whose identity could not be established.

ART. XLV.—*The Matawan Formation of Maryland, Delaware, and New Jersey, and its relations to overlying and underlying Formations;* by WM. BULLOCK CLARK.

THE name Matawan was proposed by the author in an article published in the Journal of Geology in 1894 and was there described as equivalent in a general way to the term Clay Marls of Professor Cook. The chief characteristics of this series of strata had been briefly discussed, however, two years earlier in the Annual Report of the State Geologist of New Jersey for 1892. In this earlier publication the separation of the deposits into a lower clayey and an upper sandy member was indicated, although the names Crosswicks clays and Hazlet sands were not introduced until 1897 in an article published in the Bulletin of the Geological Society of America.

The work of the writer on the Cretaceous stratigraphy of the Middle Atlantic Coastal Plain has been conducted primarily for the U. S. Geological Survey, and was started in Monmouth County, New Jersey, beginning in 1891. The results of these early investigations, published the following year in the Annual Report of the State Geologist of New Jersey for 1892, which was accompanied by a "preliminary geological map," represent mainly the conclusions which were reached from a study of that local district. A wider extension of the studies after 1891, both in New Jersey and Maryland, led to the preparation of the fuller article published in the Bulletin of the Geological Society of America in 1897, in which certain modifications were made in earlier views. The practical completion of the detailed mapping of the Cretaceous formations in New Jersey and in Maryland the present season has now led, it is believed, to a fairly close approximation to a correct interpretation of the conditions represented in the entire province between the Potomac and the Raritan rivers. In the light of the Maryland work, the earliest maps prepared in New Jersey have been more or less modified in local details, although the general results remain the same.

In a discussion of the Coastal Plain formations of Maryland and New Jersey, it should be borne in mind that the entire series of Upper Cretaceous deposits amount to scarcely five hundred feet in total thickness, and that the beds, as far as known, are practically conformable throughout. Beginning with clays and sands slightly glauconitic, they pass over into greensand marls. Five formations have been defined and mapped, and several subdivisions of most of these formations described by the writer.

In order that the conclusions reached by the author and his associates may be clearly understood, the following discussion of the stratigraphic relations of the Matawan formation is

introduced. With the extension of the work southward from Monmouth County, and more particularly with the study of the stratigraphy in Maryland, we soon came to the conclusion that the reddish brown sands (Mt. Laurel sands, called Wenonah sand by the New Jersey Geological Survey) beneath the Lower Marl bed (Navesink marls) properly belonged with the Navesink marls and Redbank sands above rather than with the Matawan below. The Redbank sands were found to disappear in about the latitude of Philadelphia, bringing the Navesink marls in Camden, Gloucester, and Salem counties, New Jersey, into immediate contact with the Rancocas marls above, from which, however, they can be separated by their contained fossils and by their more or less distinctive materials. The Monmouth formation was established to embrace the three beds.* In Maryland, however, no such differentiation of the Monmouth is discernible, the only deposits found between the Matawan formation below and the Rancocas formation above being more or less homogeneous red sands, glauconitic from base to top. Earlier attempts to maintain the New Jersey subdivisions in Maryland have not proven satisfactory.† A proper division of the Cretaceous deposits would therefore call for a drawing of the line between the Matawan and Monmouth formations below rather than above the Mt. Laurel sands.

A lens of clays and interbedded sands lying beneath the typical Matawan at Cliffwood, New Jersey, on the shores of the Raritan Bay, and included by the writer in that formation in his "Preliminary Geological Map of portions of Monmouth and Middlesex counties, New Jersey," accompanying the report of the State Geologist for 1892, has been the subject of much discussion of late, although none of the views thus far advanced seem to afford an adequate explanation of the conditions there presented. The clays, which are more or less micaceous and at times sandy, possess many features in common with the typical Matawan deposits above, even to the occurrence now and then of patches of glauconite.‡ The interbedded sands, as well as the lack of continuity of the clay beds, suggest, on the other hand, conditions characteristic of the Raritan, although the deposits as a whole show quite marked differences from the typical

*Bull. Geol. Soc. Amer., vol. viii, pp. 315–358, 1897.

†The idea has been advanced that the Maryland Monmouth may perhaps represent the Mt. Laurel sands alone, and that the Navesink marls along with the Redbank sands have disappeared in Maryland, but the long distance between the last outcrop in New Jersey and the first occurrence on the west side of the Delaware Bay renders it unwise to draw such a conclusion from the data now at hand. The deposits have furnished, to be sure, specimens of *Belemnitella americana*, which is a distinctly lower Monmouth form farther north, but as they did not come from the higher beds of the Delaware-Maryland strata the evidence is not conclusive.

‡Mr. E. W. Berry, on a recent visit to the locality, removed a small envelope full of glauconitic material from one of these patches below the debatable contact of the Matawan. The writer has also found glauconite in these beds, although the patches are very infrequent.

Raritan beds. The most important feature connected with this occurrence is the presence of a typical Cretaceous marine fauna,* part of the species being similar to the overlying Matawan, and a flora* containing many representatives of genera more recent than those in the Raritan below. Mr. E. W. Berry,† who has recently studied this flora, finds that only 37 per cent of the forms occur in the Raritan and among these the oldest and most characteristic types are lacking. In an earlier communication I referred to the lack of a clear line of separation between these beds and the typical Matawan above. At the time of my first and only study of the occurrence, thirteen years ago, the sections were much less distinctly exposed than at present, slips obscuring the upper beds. I felt in much doubt at the time as to whether the beds belonged to the Matawan above or to the Raritan below, and although I at first regarded them as Raritan and so mapped them, I finally decided to refer them to the Matawan and changed my lines accordingly before publication. On a recent visit to the locality I found the line of contact clearly shown, and it is evident that the Cliffwood clays represent an older horizon than the basal Matawan elsewhere exposed. Messrs. Kümmel and Knapp in the recent Clay Report of the New Jersey Survey, have referred these beds to the Raritan, but from their structural relations, lithologic character, and contained fossils it is apparent that it is equally impossible to refer them to that formation. All of these features indicate that these deposits constitute a transitional zone between the Raritan below and the Matawan above, and that they should be given independent rank as a formation.

A study of the basal contact of the Matawan formation from the Potomac to the Raritan rivers shows that the Matawan rests on successively later deposits northward, thus indicating a gradual transgression of the Matawan over the Potomac formations southward. Near the Potomac river the Matawan overlies the Patapsco formation, but farther north the Raritan soon appears. In approaching the Severn river and on the Eastern Shore of Maryland, deposits that suggest the Cliffwood beds occur between the typical Raritan and Matawan. In Delaware and also in southern New Jersey similar deposits have been found by the author and his associates, marine fossils occurring in the beds at Bordentown. Characteristic concretions of iron carbonate, frequently fossiliferous, have been found all the way from the shores of the Chesapeake to Cliffwood on the Raritan, although marine fossils have not been observed south of Bordentown. These deposits are significant in furnishing the earliest known Coastal Plain marine fauna, a fauna which apparently contained the first strictly marine types of life to migrate into the

* Hollick, A., The Cretaceous Clay Marl Exposure near Cliffwood, N. J., Trans. N. Y. Acad. Sci., vol. xvi, pp. 124–136, pls. xi–xiv, 1897.

† Bull. N. Y. Bot. Garden, vol. iii, No. 9, pp. 45–103, pls. 43–57, 1903; Amer. Geol., vol. xxxiv, pp. 253–260, pl. xv, 1904.

basin of Potomac sedimentation. It is possible that the Island Series of Professor Ward farther north may also prove to be the equivalent of these beds, although the exact stratigraphic limits of the former are not quite clear.

Uhler* in 1892 described what he termed the "Alternate Clay Sands" overlying his Albirupean (in part Raritan) formation in Maryland, and Darton† in 1893 proposed the name Magothy formation for these deposits, stating that they constituted a well-defined stratigraphic unit between the Potomac formation below and the marine Cretaceous deposits (Matawan, etc.) above. He, as well as Shattuck,‡ regarded certain of the clays, which unquestionably underlie the true Matawan formation, as part of the Matawan, and the similarity of the materials would often suggest this reference. Recent work by the writer and his associates both in Maryland and in New Jersey, as well as along the Delaware and Chesapeake Canal§ in Delaware, shows that a series of deposits, lying between the Matawan above and typical Raritan below and consisting of alternating beds of dark clays and light sands, the latter frequently brown in color, or of one or the other, as the case may be, and having a thickness of from 10 to 100 feet or more, can be traced almost continuously from the western shores of the Chesapeake Bay in Maryland to the Raritan Bay in New Jersey. Darton was evidently the first to name this formation should it be ultimately shown to represent a single stratigraphic unit. In the absence of satisfactory exposures in Maryland a critical study of the plant remains is demanded before final judgment can be passed. It is highly probable, however, that the Maryland strata represent a somewhat lower horizon than the fossiliferous beds at Cliffwood, and may be the equivalent, in part at least, of the "laminated sands" which underlie the lignitic beds at Cliffwood. The base of Darton's Magothy may thus prove to be the base of the "laminated sands" and may necessitate the transfer everywhere of certain upper sands hitherto regarded as Raritan to the Magothy-Cliffwood series.

The Matawan formation in New Jersey, as previously stated, has been divided by the author into the Crosswicks clays and Hazlet sands, the former corresponding to the Merchantville clay and the Woodbury clay and the latter to the Columbus

* Uhler, P. R., Trans. Md. Acad. Sci., voi. i, pp. 200, 201, 1892.

† Darton, N. H., this Journal, ser. iii, vol. xlv, pp. 407–419, 1893.

‡ Shattuck, G. B., Md. Geol. Survey, Cecil County Report, pp. 158, 159, 1902.

§ The section in the Deep Cut of the Delaware and Chesapeake Canal is one of the best in the Coastal Plain and shows the Matawan resting on the clays and sands of the Magothy formation, which at this point are in places highly lignitic. The Matawan formation consists at the base of chocolate-colored marls 15 to 20 feet in thickness overlain by black micaceous sandy clays 10 to 12 feet in thickness, which together apparently represent the Crosswicks clays. Above these beds is a more sandy member distinctly glauconitic that may perhaps represent the Hazlet sands farther north. At the eastern end of the Deep Cut the red sands of the Monmouth occur with fossils characteristic of the lower Monmouth in New Jersey.

sand and the Marshalltown sand and clay of the New Jersey Geological Survey.*

The Matawan formation gradually thins from about 220 feet on the shores of the Raritan Bay to less than 20 feet along the Potomac, where the formation finally disappears. The country throughout much of this distance of nearly 200 miles is more or less thickly covered with deposits of Pleistocene age which make it impossible to trace the beds continuously, although the numerous well-borings have greatly aided in the interpretation of the deposits. For cartographic purposes, on the scales adopted by the U. S. Geological Survey and the Maryland Geological Survey, it has not been thought desirable to attempt the mapping of the subsidiary divisions of the Matawan, although this is reported to have been successfully accomplished for the State Geological Survey of New Jersey by Mr. G. N. Knapp, who has recognized four members in the Matawan, known from below upward as the Merchantville clay bed, the Woodbury clay bed, the Columbus sand bed, and the Marshalltown sand and clay bed,† which he has extended practically across the State of New Jersey, although the Columbus sand bed 100 feet thick in Monmouth County is represented as reduced to 20 feet at Swedesboro and "farther southwest it seems to pinch out." These beds, because of the different physical conditions attending their formation, are reported by the State Geologist of New Jersey to show minor differences in their faunas, these faunules being recognized wherever the deposits appear. These subdivisions cannot, however, be satisfactorily recognized in Maryland, where the Matawan possesses greater homogeneity, being throughout predominantly a micaceous sandy clay.‡ Similar faunal differences commonly appear with lithologic variations, and in Maryland many such occurrences have been recognized and described in the Paleozoic and Tertiary formations, although from their size it has not seemed wise to cartographically represent them.

Many attempts have been made to correlate the Atlantic Coast Cretaceous deposits with other American and with European formations. In an earlier paper the author referred to the Senonian and Danian affinities of the higher Cretaceous formations in New Jersey, while the paleobotanists have regarded the lower Cretaceous formations to be the equivalent

* See description of these beds in vol. vi, Final Rept. of the State Geologist of New Jersey, pp. 155–161.

† These names first appeared in print in the Annual Report of the State Geologist for 1898 published in 1899, although the field work was started some years earlier.

‡ The more sandy character of the upper Matawan is still recognized in Cecil County but becomes largely lost in Kent County where the black micaceous sandy clay increases, and is found in the upper as well as the lower beds. Farther south no differentiation in the formation appears possible and the deposits become mainly black micaceous sandy clays throughout, although the few feet of the lower and often slightly darker beds of the undifferentiated red sands above may possibly represent the upper Matawan farther north.

of the Neocomian and Gault of Europe. The Cliffwood clays are considered by Professor Hollick and Mr. Berry to show Cenomanian characteristics in the flora, and a study of the fauna will doubtless throw much important new light upon this division of the Cretaceous.

It is evident, therefore, that the Atlantic Coast Cretaceous formations represent a considerable part of the European series, although the data at hand are insufficient as yet for complete correlation of the several horizons.

In the following table an approximate correlation of the Atlantic Coast Cretaceous formations is suggested.

Age.			Formations.	Members.	
Eocene			Sharkriver 10–15 ft.		
Cretaceous	Upper	Danian	Manasquan 30–50 ft.		Marl and Clay-Marl Series
			Rancocas 30–125 ft.	Vincentown Limesands	
				Sewell Marls	
		Senonian	Monmouth 30–200 ft.	Redbank Sands	
				Navesink Marls	
				Mt. Laurel Sands (Wenonah Sand of N. J. Geol. Survey)	
			Matawan 20–220 ft.	Hazlet Sands Marshalltown Sand and Clay bed Columbus Sand bed	
				Crosswicks Clays Woodbury Clay bed Merchantville Clay bed	
	Lower	Cenomanian	Magothy and Cliffwood beds 10-100 ft.		Transitional deposits
		Albian-Neocomian	Raritan 200–400 ft.		Potomac Group
			Patapsco 150–240 ft.		
Jurassic (?)			Arundel 0–125 ft.		
			Patuxent 50–100 ft.		

Geological Laboratory, Johns Hopkins University.

Art. XLVI.—*The Precipitation of Barium Bromide by Hydrobromic Acid*; by Norman C. Thorne.

[Contributions from the Kent Chemical Laboratory of Yale University—CXXXI.]

In former articles from this laboratory,* processes for the separation and determination of certain chlorides, hydrous or anhydrous, by the action of hydrochloric acid have been studied. The present article deals with the similar separation and determination of barium bromide by the agency of hydrobromic acid.

The hydrobromic acid used in the experiments to be described was prepared by dropping from a stoppered funnel liquid bromine into naphthalene dissolved in kerosene, passing the hydrogen bromide evolved through a purifying tower charged in layers with glass-wool and red phosphorus and a water trap, and saturating distilled water with the gas thus purified.

Pure barium bromide was made by dissolving barium chloride in water, precipitating barium carbonate by ammonium carbonate and ammonium hydroxide, washing the precipitate by decantation and dissolving it in hydrobromic acid. This solution of barium bromide was evaporated to dryness and the barium bromide thus obtained was used in the following experiments.

In the first series of experiments a weighed amount of the barium bromide was dissolved in the least volume of water, and treated with hydrobromic acid or with a mixture of hydrobromic acid and ether in equal volumes. The liquid was saturated with hydrobromic acid gas and filtered upon asbestos, and the precipitate washed by a mixture of hydrobromic acid and ether, dried in air bath or over Bunsen flame and weighed as $BaBr_2$. The details of these experiments are given in Table I.

Table I.

$BaBr_2$ taken. grm.	HBr. cm^3.	HBr and ether. cm^3.	$BaBr_2$ found. grm.	Error. grm.
0·2932	30		0·2934	+0·0002
0·1264	30		0·1260	−0·0004
0·1134	30		0·1132	−0·0002
0·1347		30	0·1367	+0·0020
0·1040		30	0·1035	−0·0005
0·0744		20	0·0748	+0·0004
0·1197		30	0·1211	+0·0014
0·4327	30		0·4345	+0·0018

* This Journal (3), xliii, 521 (Mar); (4), ii, 416 (Gooch and Havens); (4), iv, III (Havens); (4), vi, 45 (Havens); (4), vi, 396 (Havens).

Considerable difficulty was had in drying the barium bromide so as to obtain a constant weight, and the barium bromide prepared in the manner described did not dissolve completely. The results of these experiments are thereby lacking in uniformity. Presuming that the source of inaccuracy is to be looked for in the formation of an oxybromide, the precipitate in the next experiments, after filtering upon asbestos, was treated with ammonium bromide and then dried over a radiator,—at first at a low temperature and finally at a temperature high enough to drive off the ammonium bromide. When the thermometer inside of the radiator showed a temperature of 250° C. all the ammonium bromide disappeared and left a barium bromide which gave constant results, as shown in the following table.

TABLE II.

$BaBr_2$ taken. grm.	HBr and ether. cm^3.	$BaBr_2$ found. grm.	Error. grm.
0·1330	30	0·1534	+0·0004
0·1013	30	0·1016	+0·0003
0·2769	30	0·2760	−0·0009
0·2359	30	0·2353	−0·0006
0·1580	30	0·1579	−0·0001
0·2955	30	0·2947	−0·0008
0·2822	30	0·2813	−0·0009
0·1962	30	0·1962	0·0000
0·4127	30	0·4125	−0·0002
0·2751	30	0·2750	−0·0001
0·3181	30	0·3183	+0·0002
0·3049	30	0·3039	−0·0010
0·3754	30	0·3752	−0·0002

These results indicate plainly that barium bromide, prepared in a state of purity and free from oxybromide, may be completely precipitated from solution in water by treatment with a mixture of hydrobromic acid and ether in equal parts and saturation of the liquid with hydrogen bromide.

Some experiments in which precipitation was effected by a mixture of concentrated hydrobromic acid and ether in equal parts, without saturating with the gas, led to similar results. In these experiments the material weighed out was the crystallized hydrous barium bromide, $BaBr_2 . 2H_2O$.

TABLE III.

$BaBr_2 . 2H_2$ taken. grm.	HBr + ether 1:1. cm^3.	$BaBr_2$ found. grm.	$BaBr_2$ calculated. grm.	Error. grm.
0·2008	30 cc.	0·1793	0·1790	+0·0003
0·2041	30	0·1822	0·1820	+0·0002
0·2047	30	0·1821	0·1825	−0·0004
0·2171	30	0·1937	0·1936	+0·0001
0·3101	30	0·2768	0·2765	+0·0003
0·5035	30	0·4496	0·4490	+0·0006
0·5015	30	0·4476	0·4473	+0·0003

The action of hydrobromic acid upon barium chloride was next studied, with or without the presence of salts of calcium and magnesium.

A weighed amount of barium chloride, $BaCl_2 . 2H_2O$, was dissolved in the least volume of water and treated with a mixture of hydrobromic acid and ether in equal volume. The whole solution was saturated with hydrobromic acid gas, filtered upon asbestos, and then, to make sure that no barium oxybromides might be formed, treated with ammonium bromide, dried and weighed as $BaBr_2$.

TABLE IV.

$BaCl_2 . 2H_2O$ taken. grm.	$CaCO_3$. grm.	$MgCO_3$. grm.	HBr + ether 1:1. cm³.	$BaBr_2$ found. cm³.	Theory as $BaBr_2$. grm.	Error in $BaBr_2$. grm.
0·2253	----	----	30	0·2744	0·2741	+0·0003
0·2088	----	----	30	0·2538	0·2540	—0·0002
0·3273	----	----	30	0·3975	0·3982	—0·0007
0·3177	----	----	30	0·3864	0·3865	—0·0001
0·5041	0·5000	----	30	0·6134	0·6143	—0·0009
0·5083	0·5000	----	30	0·6185	0·6191	—0·0006
0·5046	0·5000	----	30	0·6139	0·6136	+0·0003
0·5022	0·5000	----	30	0·6110	0·6104	+0·0006
0·5018	0·5000	----	30	0·6106	0·6108	—0·0002
0·5007	----	0·3000	30	0·6087	0·6092	—0·0005
0·5048	----	0·3000	30	0·6144	0·6142	+0·0002

From these results it is obvious that barium may be separated and determined as the bromide in presence of salts of calcium and magnesium; and it appears also that when the proportion of hydrobromic acid to the barium chloride is that of the experiment and the precipitate ignited with ammonium bromide, the results are in practical accord with those which should be obtained if the precipitate consists entirely of barium bromide.

On the other hand, it appears from the following series of experiments that when a sufficiency of hydrochloric acid is added to the water solution of barium bromide the precipitate falls practically as the chloride.

TABLE V.

$BaBr_2 . 2H_2O$ taken. grm.	HCl used. cm³.	Ether. cm³.	$BaCl_2$ found. grm.	$BaCl_2$ theory. grm.	Error in $BaCl_2$. grm.
0·2044	25	5	0·1279	0·1277	+0·0002
0·2011	25	5	0·1258	0·1257	+0·0001
0·5021	25	5	0·3138	0·3138	0·0000
0·5037	50	10	0·3148	0·3147	+0·0001
0·5020	25	5	0·3135	9·3137	—0·0002
0·3868	25	5	0·2418	0·2417	+0·0001

So it appears that precipitation is complete in presence of a sufficiency of either acid and that the precipitate will fall chiefly as the bromide or as the chloride according to the proportions of hydrobromic acid and hydrochloric acid present.

It was thought a matter of interest in this connection to test the constitution of the precipitates when incomplete precipitation is brought about by addition of one of these acids, the other being present in considerable proportion, though in amount wholly insufficient to produce by itself precipitation in the volume of water used for solution of the barium salts.

Following is the record of experiments in which 1 grm. of barium chloride, $BaCl_2 . 2H_2O$, was dissolved in water, hydrochloric acid added to incipient precipitation, and then an amount of hydrobromic acid which by itself would produce no precipitation in the water solution. The precipitate was dried and weighed, and the content in bromine determined by the method of Baubigny and Rivals.*

$BaCl_2 . 2H_2O$ taken. grm.	Water for solution. cm^3.	HBr added. cm^3.	HCl added. cm^3.	Precipitate. grm.	Bromine in precipitate. grm.	$BaBr_2$ in precipitate. grm.
1.	30	3	22	0·5037†	0·0129	0·0240
1.	42	5	31	0·6241‡	0·0141	0·0263
1.	40	5	30	0·6338‡	0·0202	0·0375

The meaning of these results seems to be that the precipitation of the bromide is induced by the action of the hydrogen chloride upon the solvent, water. The production of free bromine ions and barium ions to the amount of the solubility product of barium bromide in water is, under the conditions, an impossibility. If this be admitted, it seems highly probable that precipitation of barium chloride is likewise conditioned by the action of the hydrogen chloride upon the solvent.

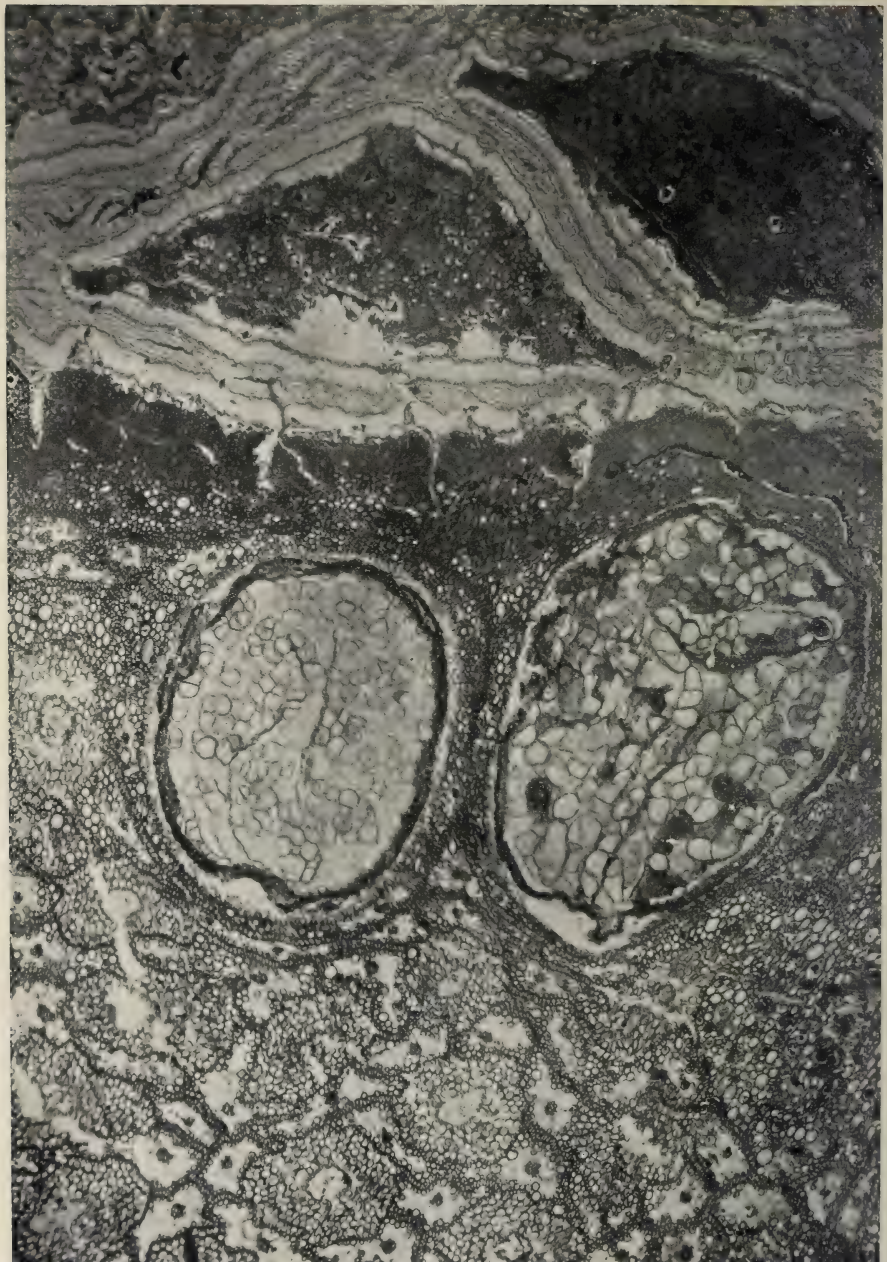
It has been customary on the part of some to explain the similar precipitation of other chlorides soluble in water, like sodium chloride, by large amounts of hydrochloric acid upon the assumption that insolubility is due to increased concentration of the chlorine ions, and such processes have been held to be typical of processes in which precipitation is affected by concentration of the free ions. It seems more probable, however, that it is the action of the hydrogen chloride upon the solvent which is the effective thing in such precipitations, as in the precipitation of barium bromide, after addition of hydrochloric acid, by an amount of hydrobromic acid wholly insufficient to cause precipitation in the water solution.

I wish to express my thanks to Prof. Gooch for suggestions and advice given during the progress of this work.

* Compt. rend., cxxv, 527, 607.

† Dried three months in desiccator over sulphuric acid.

‡ Dried 6 hours at 80° and 12 hours in desiccator over sulphuric acid.



Cycadeoidea Wielandi. S. 394. × 30.

Portion of a transverse section of an ovulate cone, cutting exterior bracts above and two adjacent proembryos filling the seed cavities, as surrounded by the mass of seed pedicels and interseminal scales.

ART. XLVII.—*The Proembryo of the Bennettiteæ;* by G. R. WIELAND. (With Plate XX.)

DURING the course of the preparation and study of large numbers of sections made from many different fossil cycad trunks representing various stages of growth and fructification, no more important feature has been discovered than the *proembryos*, of which various examples have been observed in several different fruits of *Cycadeoidea* from the Black Hills. As no developmental stage, if the archegonia of *Cycadinocarpus augustodunensis* be excepted, has hitherto been observed in any extinct plant, this discovery is of extreme and novel interest. It has, therefore, been deemed appropriate to present a preliminary description, to be amplified and further illustrated in the writer's memoir on the Structure of the Fossil Cycads, now nearly ready for publication by the Carnegie Institution of Washington, under whose auspices these investigations have been pursued.

Amongst the fossil cycads in the Yale collection closely resembling the so-called *Bennettites Gibsonianus* from the Isle of Wight, but still referred by the writer to the genus *Cycadeoidea*, the trunk numbered 393 is very completely silicified, and bears a number of fine ovulate cones. In the various longitudinal and transverse sections cut from these cones, nearly all the tissues are clearly indicated, and the seed bodies have reached approximately the size of those of the type of *C. (Bennettites) Gibsonianus*, found by Solms-Laubach to contain dicotyledonous embryos, nearly or quite filling the seed cavity, and hence exalbuminous, or nearly so. These are the only fossil embryos ever found. In the sections from trunk 393, as is usually the case in silicified plants, the seed cavity is often filled with more or less clear quartz, or by structures and traces of structure which cannot readily be interpreted. But there are in the present instance notable exceptions; a considerable number of the seeds, as one must conveniently call any stage of seed development which is not or cannot be specified, contain well preserved large angular to rounded proembryonal cells. These appear to fill the entire nucellar space in some of the transverse sections. Such an instance, where two adjacent seeds are finely conserved, is shown on Plate XX, enlarged thirty diameters. In other cases the large granular to rounded cells of the proembryo appear to have been but partially preserved, or else to have collapsed, carrying the nucellar wall inwards as if there had been a central cavity in the large-celled mass, as usually

clearly to be seen abutting on the wall of the nucellus. There are also especially to be noted in the transverse sections several irregular ribbon-like traces about the thickness of the cell walls, extending quite across the large-celled mass, filling or nearly filling the nucellus. These traces or rather surfaces occur too often to be considered wholly accidental, but are not supposed to be either suspensors, or tubular öspores, or cells such as precede embryo formation in *Ephedra*. Their fuller explanation doubtless awaits the preparation of more numerous sections and the comparisons they may permit. In some of the sections presumably cutting the upper half of the proembryo, as already hinted, there is a suggestion if not a clear indication that the mass of proembryo tissue was either less dense in its central regions, or, that there was actually present a small central cavity. This important point, which would indicate a fundamental agreement with the existing cycads, cannot be so readily settled as yet, since in no instance has a longitudinal section been cut from a proembryo as well preserved as the two shown in the plate. In one longitudinal section showing the lower two-thirds of a seed it is clear that the lower half of the nucellus was closely filled by the typical large undifferentiated cells making up the mass of the proembryo. In another longitudinal section, the superior end of the nucellus is seen to extend well into the tip of the seed, which is quite filled with the characteristic large-celled proembryo tissue. Unfortunately the middle region is in this instance not conserved.

There is nowhere a distinct indication of the presence of endosperm, or of any differentiation of the large-celled tissue filling the nucellar cavity, into an inner and outer zone. The proembryo tissue appears to be homogeneous throughout, except in one instance where some more elongate cells appear to rest against the nucellar wall. It is, however, to be constantly borne in mind that it is necessary to amplify the series of sections. Structure will be found in many instances illustrating not only all the features of the proembryo, but in all probability the other stages of development, including possibly the early stages of embryo formation; although it may be years before all the facts are learned, since it is so often the fortunate exceptional section which tells the story and yields the reward for the cutting of sections where preservation proves less clear.

Meanwhile it is possible in the light of these newly discovered proembros to make several highly interesting comparisons with existing gymnosperms. The *proembryo* was a term first used by Treub* in describing the embrogeny of *Cycas*. In

* Ann. Jard. Bot., Buitenzorg, ii, 1881, and iv, 1884.

this genus the oöspore enlarges at the expense of the adjacent tissue. Later free nuclei become very abundant in the central region, and then disorganize, all the cytoplasm massing at the base of the spore, and parietally, with a single parietal layer of equidistantly imbedded nuclei, except at the base, where there is some massing of nuclei. *Still later the sac-like cavity of this stage is partly filled up by tissue preceding suspensor development.* The proembryo of *Cycas* is, in a word, sac-like, and the endosperm large, the size of the latter in a way corresponding to the excess in size of the whole seed over that of the Bennettiteæ.

In *Gingko*, after repeated nuclear division of the oöspore, there is no parietal grouping, but instead the oöspore enlarges and comes to be compactly filled with undifferentiated cellular tissue, in which proembryo, suspensors, and embryo are all merged. This must clearly now be regarded as absolutely the most primitive condition known amongst the existing gymnosperms.

In the organization of the *Gingko* embryo, the mass of tissue just noted as filling the entire oöspore takes part, the endosperm being directly invaded without the formation of suspensors. Two cotyledons remarkably like those of the Bennettiteæ in both size and general appearance are produced; but their earliest stages have unfortunately not been figured so far as known to the writer.

Comparison with the other gymnosperms shows that the proembryo of the Bennettiteæ is unique in occupying the entire nucellus, although this character loses not a little of its isolation from the fact that the nucellæ of the existing Cycads are almost of the same size, increase in the size of the seed having been plainly bound up with endosperm development. Again it is supposable that a progressive reduction of endosperm had taken place in the Bennettitæ and was perhaps a cause of the disappearance of the group.

The most distinct agreement of the Bennettitean proembryo is clearly with *Gingko*, long known to have much in common with some ancient Cycadean ancestry or relationship. In both these proembryos, as has been seen, large-celled homogeneous tissue fills the oöspore, and the formation of dicotyledonous embryos takes place without the intervention of suspensors. The present discovery unmistakably determines for the first time that the embryogeny of *Gingko* is the most primitive amongst existing gymnosperms.

Between the existing Cycads and the Bennettiteæ the comparison is a more general one, there doubtless having been agreement in the early history of both, and the more general facts favoring the inclusion of the Bennettiteæ within a single great group, the Cycadales.

Art. XLVIII.—*Minerals from the Clifton-Morenci District, Arizona;** by W. Lindgren and W. F. Hillebrand.

In 1902 an examination was made of the Clifton-Morenci copper district in Arizona. Study of the collections proved the presence of several interesting minerals, a brief account of which is here given. The copper deposits at Clifton and Morenci consist in part of irregular or tabular bodies of oxidized ores in Paleozoic limestones, partly of chalcocite ores connected with fissure veins in a granite porphyry or in the same limestones.

Coronadite.—On the dump of a small shaft on the west end of the Coronado vein, three-fourths of a mile west of Horseshoe shaft, fairly large amounts of a dark metallic mineral were found intimately intergrown with quartz and decomposing into limonite. The vein at this end shows no copper minerals but is stated to contain some gold and its surface ores are reported to have been worked in an arrastre in the early days of the camp. In color this mineral is black and its structure delicately fibrous. The hardness is about 4 and the streak black with brownish tinge.

A thin section proves it to be opaque and in reflected light its fibrous and homogeneous structure is well brought out. It cements angular quartz grains and its secondary nature is clearly indicated. In general aspect it is not unlike psilomelane. A preliminary examination showed that it contained the oxides of lead and manganese; as it did not seem to correspond to any known mineral species, a separation and analysis was made. The results were as follows:

Long continued efforts to secure pure material for analysis by the use of heavy solutions were not attended with success. The ultimate product of specific gravity, 5·246 at 22°, yielded on decomposition by hydrochloric acid a residue of from 6 to 7 per cent, which consisted mainly of silica, with a small amount of alumina, etc. Its presence would not have mattered much had it been quite indifferent to acids, but its partial solubility, as shown by the varying amounts undissolved on different trials and similar varying amounts of alumina and perhaps other minor ingredients found in solution, renders the calculation of molecular ratios not altogether certain in all cases. The composition as found is:

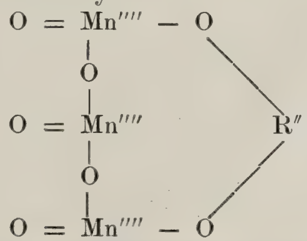
* Published by permission of the Director of the U. S. Geol. Survey.

MnO_2	56·13*
MnO	6·56
PbO	26·48
ZnO	0·10
CuO	0·05
MoO_3	0·34
Al_2O_3	0·63†
Fe_2O_3‡	1·01
H_2O	1·03§
Insol. and silica	7·22
CaO, MgO, Alk., and loss	0·45
	100·00

The material available did not admit of determining quantitatively the vanadium, which may be present in rather more than a mere trace, but neither it nor the phosphorus can influence materially the ratios given below. The vanadium would be effective in two ways: (1) by requiring a base for its neutralization, if existing as an acid constituent, and (2) by liberating chlorine when acted on by hydrochloric acid, and thus affecting the values found for peroxide oxygen. If the iron exists in the ferrous state, it too would affect the values found for the peroxide oxygen and consequently for both the oxides of manganese. Assuming it to so exist and applying the proper corrections, also deducting from the lead oxide an equivalent for the molybdenum, assuming its existence as molybdate of lead, the following are the results:

MnO_2	56.68 ÷ 87	= ·6515			= 3·00
MnO	6·11 ÷ 71	= ·0861	}		
PbO	26 96 ÷ 222·9	= ·1165			
FeO	0·91 ÷ 72·	= ·0126		0·217	= 1·00
ZnO	0·10 ÷ 81	= ·0012			
CuO	0·05 ÷ 79	= ·0006			
H_2O	1·03 ÷ 18	= ·0572			= 0·264

If the mineral is to be regarded as anhydrous, the comparatively simple formula $R''(Mn_3O_7)''$ satisfies the above ratio, and it may be written structurally:



* Mean of 56·10 and 56·13. Total Mn as MnO from $MnSO_4$, 52·38 per cent. Peroxide oxygen 10·31 per cent.

† With a little TiO_2, P_2O_5 and V_2O_5. ‡ State of oxidation not known.

§ Nothing at 100°, only 0·14 per cent below 200°.

in which $R'' = Pb''$ or Mn''. This is to be regarded as a saturated salt of one of the numerous possible derivatives of ortho-manganous acid that may be derived from it by removal of water, in the present case as follows:

$$3H_4MnO_4 - 5H_2O = H_2Mn_3O_7$$

An acid of the same empirical formula would result by removal of two molecules of water from three of metamanganous acid, H_2MnO_3.

It is probably best to rest for the present content with the above relatively simple formula and to regard the water found as due to incipient alteration. But if the water is to be considered as wholly or in part essential, and furthermore constitutional—and this may very well be the proper view to take—then the formula becomes much more complex, namely $R_4''H_2 (Mn_{12}O_{29})$, when none of the water is allotted to the foreign matter. This formula is still referable graphically to a more highly condensed manganous acid, and a number of isomers would be possible.

Such intricate formulas as this should not cause the least surprise, however unlikely they may at first appear to be. The great number of manganites, in varying degrees of saturation and hydration, observed in nature and prepared artificially, some of them of even greater complexity that the above, are certainly not all mixtures of only a few simply constituted molecules. A very short study of the graphic formula corresponding to the above empirical formula $R''_4H_2 (Mn_{12}O_{29})$ will show what a vast number of closely related bodies are theoretically possible by hydrating the molecule step by step, or by adding to or reducing the number of divalent atoms, or substituting for them those of another valence. Similar varieties in great number would be derivable from other condensed manganous acids of both higher and lower orders, and it is plain that because of the very slight differences in percentage composition between many of them, it is almost as hopeless to expect analysis to reveal the exact empirical formula in the majority of cases as it is for the enormously complex albuminous bodies of organic chemistry. This is especially true because in so many cases the mineral manganites described are far from being homogeneous species. They are either mixtures of two or more of these closely related complex molecules, or else are contaminated by foreign bodies. It is not surprising then that so many compounds of uncertain formula that may be regarded as salts of manganous acid have been prepared in the laboratory or are found in nature. From the known tendency of these bodies to form under laboratory conditions which may very well be repeated in their general character in nature, it is to be expected

that a vast number of mineral manganites should exist, and it ought rather to excite surprise than otherwise if two or more are not formed simultaneously from the same solution. This, together with inherent difficulties of analysis, would offer a simple explanation of the fact that so few of the analyses made lead to rational formulas. If formed from solution their original state might well be one of hydration either as regards water of crystallization or of constitution. The temperature at which the water is expelled in the present case indicates constitutional water.

Our search of the literature has not revealed a native manganite carrying a high percentage of lead, although artificial compounds have been prepared. For this reason, and because of its distinctly crystalline character, the present mineral seems worthy of receiving a specific name. The one we propose is *Coronadite*, after the famous explorer of that portion of the American continent from which the Territories of New Mexico and Arizona have been formed.

Chalcocite (Cu_2S).—The cuprous sulphide is very common in the Clifton district, in fact constituting at present the principal valuable mineral in the ores. It occurs chiefly intergrown with pyrite, in the altered porphyry as disseminated grains or as solid seams or veins which rarely exceed two or three feet in thickness. It is never crystallized but has ordinarily an earthy or sooty appearance and black color; scratching it with a knife reveals the semi-sectile character and metallic luster. In a few small massive veinlets the normal metallic luster and dark gray color appear on fractures; a fibrous or columnar structure of the mineral is known on small seams in shale from the Montezuma mine. The mineral prefers porphyry, and the great bodies of ore now worked all occur in this rock; but it is not entirely unknown from the irregular deposits in limestone generally carrying cuprite and copper carbonates. A partial analysis of massive chalcocite from the Montezuma mine, Morenci, gave 96 per cent Cu_2S and 2·4 per cent FeS_2, the latter probably mechanically admixed.

The chalcocite is everywhere, in this district, a secondary mineral formed by the replacement of pyrite by means of descending solutions of cupric sulphate. The deposition of the mineral was accompanied by the formation of quartz, chalcedony, and kaolin. In the porphyry the chalcocite ore along the veins begins 100 to 200 feet below the surface and continues to a depth of 400 feet, or even more, when it is usually replaced by pyrite, chalcopyrite, and zincblende.

Silicates.

Willemite (Zn_2SiO_4).—This rare silicate of zinc was found by Mr. Boutwell as very small greyish crystals on a fragment

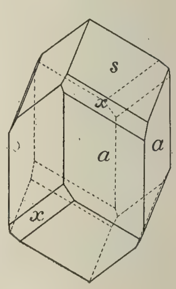
of garnet rock in the Modoc open cut, on the north side of Modoc Mountain. These crystals were identified by Messrs. Pirsson and Penfield of Yale University, who state that the stout hexagonal prisms look exactly like those from the original locality at Moresnet.

Calamine ($ZnOH_2SiO_3$).—Small transparent orthorhombic crystals of calamine were identified on a specimen of decomposed garnet rock from the Shannon mine, just above the lime quarry.

Dioptase (H_2CuSiO_4).—The silicate of copper, dioptase, has been found at only a few localities. Very beautiful specimens, which, however, are by no means common, have long been known from the classic locality, the Kirghese Steppes, Russia, and more recently from the French Congo State, Africa. Dioptase is seldom found in the United States, the only recorded occurrences being at the Bon Ton mines, Chase Creek, near Clifton, Arizona, noted by R. C. Hills,* and from near Riverside P. O., Pinal County, Arizona, noted by W. B. Smith.† Well crystallized specimens of this mineral were found on an old dump of the Stevens group of mines, on the west side of Chase Creek, near Garfield Gulch. They occurred in a small chimney of chrysocolla ore in limestone, now worked out, and the locality is believed to be the same as that described by Mr. Hills. The dioptase crystals were submitted to Prof. S. L. Penfield, who remarks on them as follows:

"The crystals, measuring from 1^{mm} to 2^{mm} in diameter, occur closely grouped together, lining cavities in a brown ferruginous gangue impregnated with amorphous green material which is probably chrysocolla. The color of the dioptase is a beautiful emerald-green. The habit of the crystals, shown by the accompanying figure, is that which is most commonly observed and is especially characteristic for dioptase; prism of the second order $a\,(11\bar{2}0)$, terminated chiefly by the rhombohedron of the first order $s\,(02\bar{2}1)$ and with small faces of the rhombohedron of the third order $x\,(13\bar{4}1)$. As is common on this species, the prismatic faces are vicinal and the s and x faces are striated parallel to their mutual intersection edges, hence the crystals are not suited for giving accurate measurements of the angles with the reflection goniometer. One crystal was measured, and the angles of one of the rhombohedral zones, given below, are sufficiently close to the calculated values to establish the identity of the forms.

1



* This Journal (3), vol. xxiii, p. 325, 1882.

† Proc. Colorado Sci. Soc., vol. ii, p. 159, 1887.

				Measured.	Calculated.
$a\ x$,	$11\bar{2}0$	$13\bar{4}1$	=	28° 55′	28° 48′
$s\ s'$,	$02\bar{2}1$	$\bar{2}021$	=	83 48	84 33
$s'\ a''$,	$\bar{2}021$	$\bar{1}\bar{1}20$	=	48 18	47 43

By crushing some of the material, imbedded in oil under a cover glass, and examination in convergent polarized light, occasional fragments were found which gave a normal uniaxial interference figure, with numerous rings indicating high birefringence. The character of the birefringence was found to be positive. Thus in all of its crystallographic and optical relations the material studied is like typical dioptase from other localities."

Chrysocolla ($CuSiO_3+nH_2O$). — This mineral occurs very commonly in the oxidized part of the deposits, but does not, except in some cases, constitute an important ore. On the whole, it is more abundant in the deposits in porphyry and granite than in those contained in limestone. The usual bluish green or dirty green colors and conchoidal fracture characterize it. It occurs in seams or coatings at many of the mines: abundantly in the Mammoth mine on contact fissure between porphyry and limestone; at several prospects on the Stevens group in Chase Creek near Garfield Gulch; in the Terazas fissure vein in porphyry near Metcalf; at the Metcalf mines and many of the prospects between that place and Morenci; at the Modoc open cut, Morenci. Technical analyses of chrysocolla ore from Terazas mine by the Arizona Copper Company gave

SiO_2	31·65
CuO	34·90
H_2O	26·30
Al_2O_3	3·80
Undetermined	3·35
	100·00

Normal chrysocolla should have 34·2 per cent SiO_2, 45·2 per cent CuO, and 20·5 per cent H_2O, but the analyses show great divergency, many probably being mixtures. Moreover, what has been called chrysocolla probably includes two mineral species.

The optical characteristics of chrysocolla seem imperfectly known. Dana states that it is cryptocrystalline, while many other text-books, notably one issued in 1902 by Professor Miers, call it "amorphous."

In most cases the mineral indeed seems cryptocrystalline with bluish gray colors of interference. But this is by no means universal.

Chrysocolla from the Modoc open cut appears as mammillary crusts of bluish green color on "copper-pitch ore." The latter is isotropic and undoubtedly a distinct mineral from the chrysocolla, of brown color in varying tints, some of it opaque and showing evidence of concentric deposition. On top of the chrysocolla are thin crusts of quartz and some calcite. The chrysocolla has three different structural forms, as seen under the microscope: (1) The dominant mass is a cryptocrystalline to microcrystalline aggregate of particles with high birefracting index; (2) very fibrous and felted aggregates of same substance giving undulatory effects between crossed nicols and medium high colors; (3) fibrous crusts on top of 1, or also in thin layers between masses of 1, the individuals having such a remarkably parallel orientation that the aggregate of them appears almost like single crystals between crossed nicols, with black shadows sweeping across them when the table is turned. The extinction is parallel to the fibers, double refraction strong, about like augite, character negative. The same optical characteristics were repeatedly observed in thin sections of chrysocolla from Metcalf and other places. Reniform deposits were sometimes noted, the center of cryptocrystalline material coated with coarsely fibrous and highly birefringent material.

Sections from the Coronado and Metcalf mines often showed pseudomorphs of pyrite consisting of a shell of limonite with kernel of fibrous chrysocolla.

The observations of Jannettaz* on chrysocolla from Boleo Baja, California, Mexico, led to the same results as described above, but seem generally to have been overlooked by editors of text-books.

Copper pitch ore.—Under this old German name is described a dark brown to black substance, sometimes dull but generally with glassy to resinous luster; hardness about 4; streak dark brown. It occurs among the products of oxidation of the deposits in limestone, as at the Detroit and Longfellow mines and Modoc open out at Morenci, and is associated with azurite, malachite, and chrysocolla, often enclosing these minerals or replacing in branching veinlets, together with azurite, a shale-like mass, probably largely composed of kaolin. In thin section it is sometimes opaque, but often also translucent, gradual transitions obtaining in the same section, and occurs in irregular or concretionary masses, often containing small embedded crystals of a doubtful mineral, possibly a silicate of zinc. Between crossed nicols the translucent mineral always proves entirely isotropic and, except for varying depth of color and the small crystals mentioned, entirely homogeneous.

* Bull. Soc. Min. Paris, 1886, ix, 211.

A rough preliminary analysis of selected pitch black material from the Detroit mine gave

CuO	28·6
ZnO	8·4
MnO_2	21·2
$Fe_2O_3+Al_2O_3+P_2O_5$	4·0
Insoluble in H,Cl	22·8
Ignition loss 16·3, less oxygen due to conversion of MnO_2 to Mn_3O_4	13·7
	98·7

Similar material surmounted by crusts of chrysocolla from the Modoc open cut contained much MnO_2, with a good deal of CuO and ZnO, and is thus evidently the same substance. Manganese is largely but not certainly wholly present as MnO_2. The insoluble portion consists of silica, is wholly separated by acid without need of evaporation, and is nearly all soluble in dilute potassium hydroxide. It is not possible to say whether silica is in combination or as opal, but it cannot be present in any other form.

Most of these copper pitch ores, known from many districts, have been described as impure chrysocolla. As shown by the optical characteristics, they are not however a mixture and they certainly do not contain any chrysocolla, the characteristics of which are very different. They probably represent a series of closely related compounds, the chemistry of which has not yet been fully elucidated. Prof. G. A. Koenig* describes a similar mineral with the same isotropic character from Bisbee, and names it melanochalcite. Its composition is different, containing

CuO	76·88
SiO_2	7·80
CO_2	7·17
H_2O	7·71
ZnO	0·41
FeS_2	0·07
	100·04

Prof. Koenig considers it as most probably a basic salt of an ortho-silico-carbonic acid. No carbon dioxide was found in the Morenci minerals. In conclusion, it would seem that the chemistry of these copper pitch ores would bear further examination.

Morencite.—In a lime shale on the intermediate level of the Arizona Central mine, Morenci, 200 feet below the surface,

* This Journal, xiv, p. 404, Dec. 1902.

brownish or greenish spreading mases were found, containing brownish yellow, silky fibrous seams. The enclosing material consists largely of the same material as the seams, but impure and mixed with a little chlorite and pyrite. The whole bears evidence of being a product of oxidation of some contact metamorphic mineral.

The fibrous mineral on the seams forms a felted aggregate as seen under the microscope, but it is well individualized and contains few impurities except a little pyrite and chlorite. The minute fibers are brownish yellow and slightly pleochroic, being darker when parallel to the principal section (opposite the behavior of biotite); the birefringence is strong and extinction strictly parallel to the fibers. No mineral corresponding to this has been described, but, although its individual character is beyond doubt, the analysis does not lead to a satisfactory formula. The material for the analysis was picked out carefully under the lens and, examined under the microscope, it proved satisfactorily pure.

The analysis afforded the results of the first column of figures below. In deducing the molecular ratios of the second column, there has been deducted sufficient lime to form apatite with the phosphoric oxide.

		Molecular ratios.		
SiO_2	45·74	757		= 10·71 or 11
TiO_2	trace			
Al_2O_3	1·98	019	205	= 2·90 " 3
Fe_2O_3	29·68	186		
FeO	0·83	011	141	= 2·00 " 2
MnO	trace			
CaO	1·61	027		
MgO	3·99	100		
K_2O	0·20	002		
Na_2O	0·10	001		
H_2O 105°	8·84	491		= 6·96 " 7
H_2O 150°	0·12	282		= 3·99 " 4
H_2O below redness	4·27			
H_2O redness	0·69			
CuO	little			
FeS_2	0·66			
P_2O_5	0·18			
	98·89			

It would seem from the temperatures at which the water is driven off that this must exist in two conditions, and that four-elevenths of it must be held more securely than the remaining seven-elevenths. The attempt to account for four molecules of water as constitutional, however, led to no simple or seemingly

probable formula, whereas if all water is excluded the ratio is that of a metasilicate—$R''_2R'''_6(SiO_3)''_{11}$. On the other hand, to include the whole of the water as essential to the silicate molecule, for which there is little ground in view of the ease with which most of it is expelled, leads to an orthosilicate ratio—$R'_{22}R''_2R'''_6(SiO_4)''''_{11}$.

On the whole, considering also the bad summation of the analysis, it is more rational to regard the mineral as a hydration product of an original metasilicate molecule than to attempt to construct a complex formula which could have but a very doubtful value. Considering that the mineral is not a mixture, but optically well individualized, we have, after some hesitation, thought best to designate it by the name morencite, derived from the locality in which it was found.

Libethenite ($H_2Cu_4P_2O_{10}$).—This hydrous, basic phosphate of copper was found 30 feet below the adit level of the Coronado lode, in the main shoot. It is a matter of interest to record its occurrence, for this rare mineral has never before been noted in the United States. It occurs in small crystals, less than 1^{mm} in length, deposited in cavities and seams in a quartzite gangue. The mineral was identified by Prof. S. L. Penfield, who also kindly measured and figured the crystals. Prof. Penfield describes the occurrence as follows:

"The only associated minerals are occasional clusters of minute quartz crystals and small tufts of radiated malachite needles. The color of the libethenite varies from light to dark olive-green, depending upon the size of the crystals. The habit of the crystals, as shown by the accompanying illustration, is a combination of the prism m (110) and brachydome e (011), which is exactly like that commonly observed on libethenite from foreign localities. On an occasional crystal the brachypinacoid b (010) was also observed. Although the crystals are brilliant, the faces are generally vicinal and give uncertain or multiple reflections of the goniometer signal. The best reflections were obtained from the faces of the dome e, and three measurements of $e \wedge e'$, $011 \wedge 0\bar{1}1$ gave 69° 52′, 70° 18′ and 70° 14′. The last measurement, obtained from the best reflections, is close to the value, 70° 8′, obtained by Rose. The best measurements of the prismatic angle gave $m \wedge m'''$, $110 \wedge 1\bar{1}0 = 87° 11'$, which, considering the vicinal character of the prismatic faces, is reasonably close to the value of Rose, 87° 40′, as given in Dana's Mineralogy. A small crystal resting on a prismatic face, when examined in convergent polarized light, showed an optical axis nearly in the

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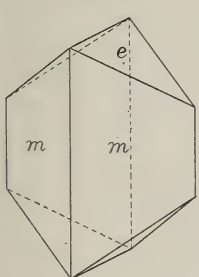

center of the field with the dark bar running at right angles to the vertical axis, thus indicating that the optical axes are in the plane of the base, as determined by Des Cloizeaux. The presence of copper, water and phosphoric anhydride was determined by chemical tests."

A more detailed search would probably reveal small quantities of phosphates from other mines near Morenci. They are certainly not abundant.

Brochantite ($H_6Cu_4SO_{10}$).—This basic sulphate of copper is usually supposed to be one of the rarer minerals. It was, however, discovered at a few places near Metcalf and Morenci, in well developed crystals, and this led to a systematic microscopic examination of the green ores, hitherto supposed to be malachite. The result was surprising, as the mineral was proved to be of extremely common occurrence, mostly intergrown with malachite, which had effectively masked its presence. It is believed that a careful examination of many so-called malachites from other districts will disclose the overlooked importance of brochantite as a copper ore.

Brochantite is frequently crystallized in the short but stout rhombic prisms combined with dome and brachypinacoid characteristic of the species. Needle-shaped and flat crystals are more rare. The crystals are usually of small size and frequently microscopic. It occurs as lighter or darker emerald-green crusts on limonite or sericitized porphyry from the Red ore body in the Shannon mine, from the Metcalf mines and many other places; as fine-grained aggregates in altered porphyry at the Shannon mine, near the surface, and constituting valuable ore with up to 30 per cent copper; from croppings of the King vein, filling seams and coating porphyry fragments as flat pieces or even foils with almost pearly luster; from the croppings of the Copper Queen mine between Morenci and Metcalf, here as flat stellar aggregates of bluish green foils; at many places near Morenci, as, for instance, Copper Mountain and Montezuma mines, at the latter locality replacing chalcocite. It would probably not be found absent from any mine in the district containing oxidized copper ores. Malachite often develops later than the brochantite.

On the whole, the mineral is most abundant in fissure veins in porphyry, though also occurring in the irregular deposits in limestone.

Brochantite has an excellent cleavage parallel to the brachypinacoid. The macropinacoid is the axial plane and the acute bisectrix is seen emerging in cleavage foils. Pleochroism very slight. Birefringence much lower than malachite, about equal to that of augite. This, as well as the absence of twins, distinguishes brochantite from malachite. The reaction for sulphuric acid is of course a valuable aid.

Spangolite ($H_{18}Cu_6AlClSO_{19}$).—This peculiar mineral, essentially a highly basic chloro-sulphate of copper and aluminum, was discovered and described by Prof. S. L. Penfield* some fifteen years ago. The specimen came from some point within 200 miles of Tombstone, Arizona, and probably from one of the great copper camps of the territory. Somewhat later it was identified by Prof. H. A. Miers on two specimens from Cornwall, England, but the American locality has not yet been found. It is, therefore, a matter of interest to record its discovery on some specimens from the Metcalf mine of the Arizona Copper Company, taken from the workings in the great open cut not more than 100 feet below the surface. These specimens consist of white sericitized granite-porphyry, in part silicified, and traversed by veinlets and irregular masses of cuprite; the cuprite contains native copper and is covered by crusts of malachite, brochantite, and chrysocolla. A soft and scaly bluish green coating on the chrysocolla proved to consist of microscopical hexagonal crystals or cleavage foils, remaining dark between crossed nicols. The mineral was identified as spangolite, a determination in which Professor Penfield concurred. No measurable crystals were found and the mineral is very inconspicuous. It is difficult, if not impossible, to obtain material entirely free from accompanying minerals.

Selected bluish flakes from this specimen gave tests for water, and the sulphate and chlorine ions, besides copper. There was too little of this pure material to permit of a test for alumina, but the mixed copper minerals composing the greater part of the specimen showed the presence of this body. It seems therefore probable on these grounds alone that the bluish flakes are spangolite. Vanadium, phosphorus, and arsenic are absent.

The closed-tube reactions of the mixed copper minerals are very striking. Water is given off first. Then appears suddenly a white sublimate ($AlCl_3$?) near the assay, which seems to form or at once change to minute colorless drops. This deposit can be driven slowly up the tube, followed at its lower, sharply defined edge, by dark yellow-brown drops ($CuCl_2$?), which on cooling solidify to greenish crystalline aggregates, and the part of the tube between them and the assay shows under the lense delicate feathery crystallizations like frost markings on window panes. Down in the flame the glass becomes colored red (Cu_2O ?) and in parts yellow. On charcoal the blowpipe flame is colored azure blue and at the same time green.

In order to compare the above closed-tube behavior with that of undoubted spangolite, a small fragment of the latter, offered by Dr. Penfield, was tested. It gave water and then a white

* This Journal, 1890, vol. xxxix, pp. 370–378.

sublimate like the one above mentioned, followed by a dark olive-brown liquid, which on cooling passed though lighter shades of color and solidified as a bright green ring. In general this behavior is very like that of the mixture under examination from Clifton.

Gerhardtite ($H_6Cu_4N_2O_{12}$).—The cliffs of granite-porphyry in the deeply eroded Chase Creek Canyon at Metcalf in many places show a conspicuous and extensive bright green coating of some copper mineral, which, no doubt, is formed by the trickling of atmospheric waters over and through rocks containing a small percentage of copper. This is not surprising, for porphyry in this vicinity is altered throughout by quartz cementation and disseminated cupriferous pyrite. This "green paint," as it is frequently called, is not soluble in water, and more closely examined consists of small dark green, roughly mammillary forms, coating the rock to a thickness of a few millimeters. Examination by the microscope fails to reveal any recognizable mineral in the cryptocrystalline mass.

Chemical examination led to the interesting result that the copper minerals present consist of a nitrate and a chloride, neither of which has been found elsewhere in the mines of the district. Detrital grains and some silica seem associated with these compounds. The nitrogen seems difficult to account for in the absence or scarcity of animal substances which might have yielded it. Possibly it is contained in the porphyry.

The closed-tube reactions of the copper minerals forming the mixture on this specimen are as striking in their way as those of the mixture containing spangolite, described elsewhere. Water first appears, then brownish nitrous vapors, followed by a sublimate which is not very volatile, becomes black on further heating but on cooling yellow-brown. The glass at the bottom of the tube is often yellow-brown when cold. After some hours the sublimate nearly disappears or becomes greenish from absorption of water. If the water which condenses in the upper part of the tube on first applying heat is driven out by the flame, and the mouth of the tube is held in the flame, this is colored deep green by a volatile copper compound (chloride ?). On charcoal the flame is azure blue and at the same time green. Vanadium is absent.

The mixture contains presumably the basic nitrate gerhardtite and a chloride which is perhaps atacamite. Spangolite, the chloride, can hardly be present, for the slight amount of SO_3 shown by test does not seem sufficient to account for the large amount of chloride.

The only place from which gerhardtite has previously been identified is at Jerome mines in the central part of Arizona, associated with cuprite and malachite. It was discovered there by Messrs. H. L. Wells and S. L. Penfield.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *Conversion of Ammonia into Nitrites and Nitrates.* — It has been known for a long time that when air acts upon metallic copper in presence of ammonia solution, a formation of ammonium nitrite takes place along with the solution and oxidation of the copper, and it has been found, also, that atmospheric oxygen is taken up by a solution of cupric hydroxide in ammonia, with the formation of nitrite. The first of these reactions gives a small yield of nitrite in comparison with the amount of copper oxidized, while the second one takes place very slowly. W. Traube and A. Biltz have, therefore, investigated the electrolytic oxidation of ammonia in the presence of cupric hydroxide, and have found that when an ammoniacal solution of sodium hydroxide containing dissolved cupric hydroxide is electrolyzed, nearly all the oxygen liberated at the anode is utilized in converting ammonia into the nitrite. Electrodes of platinum and iron foil were used for the experiments; the latter being scarcely attacked in the alkaline solutions. When the electrolysis was prolonged it was found that the nitrite was completely oxidized to nitrate. It was found that the process gave a high percentage of efficiency in the use of the electric current on the small scale used in the laboratory, but it has not yet been ascertained that this interesting method will prove economical as a manufacturing process on the large scale.—*Berichte*, xxxvii, 3130. H. L. W.

2. *Is Tyndall's Optical Method Capable of Showing the Presence of Molecules in Solutions?*—It has been shown by Spring that it is possible to obtain aqueous solutions in which a powerful ray of light is invisible, just as Tyndall found, long ago, that such a ray was invisible in properly purified gases. Lobry de Bruyn and Wolff have recently made experiments which seem to indicate that large molecules in solution have an action upon the ray of light which is similar to that of ultramicroscopic, suspended particles. Their results are perhaps not yet conclusive, but if work on a larger scale and with better apparatus confirms these preliminary results, it will not be easy to distinguish between real and pseudo-solutions (e. g. colloidal solutions of metals), by means of the action of light.—*Recueil, Pays-Bas*, xxiii, 153. H. L. W.

3. *A New Modification of Silicon.* — Moissan and Siemens have found that silicon is more soluble in molten silver than in zinc. It was observed, moreover, that a part of the silicon was readily soluble in hydrofluoric acid, although it separated in a crystalline condition when the silver solidified. Thus, upon saturation, silver was shown to dissolve the amounts given in the following table :

Temperature.	Total Si.	Soluble.	Insoluble.
970°	9·22%	5·35%	3·87%
1150	14·89	4·02	10·87
1250	19·26	3·66	15·60
1470	41·46	6·63	34·83

It was found that when the metallic silver was only partly saturated with silicon, the proportion of the soluble modification was greater, so that when only about 2 per cent was present it was practically all soluble in hydrofluoric acid. This new modification of silicon forms thin, yellow, transparent plates, the color of which resembles the crystallized silicon made with aluminum. Its specific gravity does not vary notably from that of the insoluble modification.—*Berichte*, xxxvii, 2540. H. L. W.

4. *Phosphorescent Zinc Sulphide.*—It has been supposed that chemically pure zinc sulphide was required for the preparation of the well-known phosphorescent blende screens. In preparing such screens GRÜNE noticed, however, that the results were very variable, and when particular care was taken to use very pure zinc salts, the phosphorescence became weaker than usual. From this it was evident that traces of foreign substances improved the luminosity of the material, and direct experiments showed this to be the case. Copper was found to be the most satisfactory impurity, and less than 1/10,000 of this sufficed to produce a magnificent green phosphorescence. Silver, lead, bismuth, tin, uranium, and cadmium also gave good products, while iron, nickel, cobalt, and chromium gave negative results. When manganese was present in the zinc sulphide a very peculiar product was obtained which phosphoresced with a yellowish red light and became very luminous when it was rubbed or scratched.—*Berichte*, xxxvii, 3076. H. L. W.

5. *Atomic Weight of Rubidium.*—An elaborate investigation of the value of this constant has been made by E. H. ARCHIBALD of McGill University, Montreal. Great care was used in purifying the material, particularly in separating the last traces of potassium and cæsium, and several samples of different origin, as well as of different treatment in purification, gave only closely agreeing results. The ratios AgCl : RbCl, Ag : RbCl, AgBr : RbBr and Ag : RbBr were determined with very concordant results, giving a final mean value, when oxygen is taken as 16, as 85·485 for the atomic weight of rubidium. This result is appreciably higher than the results of most of the previous investigators, the value adopted in the international table being 85·4.—*Jour. Chem. Soc.* lxxxv, 776. H. L. W.

6. *Radio-active Cinnabar.*—It has been observed by LOSANITSCH that certain specimens of the mineral cinnabar show a distinct radio-active action upon the photographic plate, but this is not as strong as the action of pitchblende. It is the author's opinion that the radio-active constituent of cinnabar is not identical with radium, and he gives to it provisionally the name radiomercury.—*Berichte*, xxxvii, 2904. H. L. W.

7. *Materialien der Stereochemic;* von C. A. BISCHOFF. 8vo, pp. cxxxvi + 1977. Braunschweig 1904 (Vieweg und Sohn).—The two large volumes under consideration are made up of nine yearly reports on stereochemistry embracing the years 1894–1902. Each year's report is divided into four sections, treating of general stereochemistry, optical isomerism, the geometrical isomerism of optically inactive bodies, and the relations between position in space and chemical reactions. Those who have not followed closely the progress of stereo-chemistry will be surprised that so extensive a work could be written upon the investigations of nine years in this subject, concerning which nothing was heard twenty years ago. Regardless of some defects, such as slight attention to American work, the book will be found indispensable to those who are interested in this line of research. T. B. J.

8. *Die Heterogenen Gleichgewichte vom Standpunkte der Phasenlehre;* von Dr. H. W. Bakhuis Roozeboom. Vol. II, Part I, pp. 467, 8vo (Vieweg und Sohn, 1904).—The first volume of this book has already been reviewed in this Journal [4], xii, 463, 1901. The present volume is devoted to systems made up of two components in which, as solid phases only the components occur, and excluding the cases where solid compounds or mixed crystals are present. Frequent use is made of diagrams and figures in three dimensions. For students of the phase rule this book when finished should take the part that Ostwald's Lehrbuch does for students of physical chemistry in general. H. W. F.

9. *Phosphorescence.*—A long paper on this subject is contributed by P. LENARD and V. KLATT, and relates to the phosphorescence of sulphides of the alkali earths. This phosphorescence is due to those sulphides, to a small trace of certain metals, and to fusible additions. Together with the chemical nature, the physical structure conditions the character of the light. This light appears only at a glow heat, never at a cold or wet stage, and is destroyed by pressure. Care was taken to obtain definitely pure substances. The addition of small trace of metals changes the intensity of the light, and its duration. No displacement of bands in the spectrum was noticed. The authors believe that their study of the peculiarities of the emission bands gives an insight into the complex phenomena of phosphorescence.—*Ann. der Physik*, No. 12, 1904, pp. 225–282. J. T.

10. *Lippman's Color Photography.*—L. PFAUNDLER having at hand a number of Lippman photographs has made a study of "Zenker Streifer" in regard to their bearing on the color of the photographs. These streifer, or bands, are spectra or interference colors produced by the varying thickness of the photographic film. These spectra diffused over the photograph give the colors observed. The Zenker bands show that there are series of color pairs which do not contribute to a correct color mixture but which tend to neutralize to black. The Lippman method is not a full solution of color photography. It is, however, a beautiful and highly interesting physical experiment.—*Ann. der Physik*, No. 12, 1904, pp. 371–384. J. T.

11. *Change of Velocity of Cathode Rays in passing through thin Metallic Layers.*—H. Hertz first observed the passage of these rays through thin metallic screens, and showed that the rays were diffused in their passage. P. Lenard's paper on the passage of cathode rays outside the exhausted vessel into air and through various substances is well known. He found that the rays apparently suffered no change in velocity. W. Seitz came to the same conclusion. Lately E. Gehrcke showed that under constant potential differences a homogeneous beam of cathode rays after reflection from metallic surfaces showed itself non-homogeneous and the beam was spread out into a spectrum. G. E. Leithäuser has extended this work to the study of the possible change of velocity which a homogeneous cathode beam might suffer in passing through thin metallic membranes. He points out that the failure of the earlier observers to notice a change of velocity was perhaps due to their employment of Ruhmkorf coils, and he has worked with a twenty-plate Holtz machine, which gave a constant difference of potential. He thus obtains a change in velocity and confirms Gehrcke's results.—*Ann. der Physik.*, No. 12, 1904, pp. 283–306. J. T.

12. *Insulation in a Vacuum.*—Lord Kelvin calls attention to a confusion of ideas in regard to the conductivity of the ether. He prefers to call the ether a very perfect non-resister of electricity passing through it, and, therefore, that the insulation of electricity in a vacuum is to be explained not by any resistance of vacant space or of ether but by a resistance of glass or metal or other solid or liquid against the extraction of electrions from it, or against the tearing away of electrified fragments of its own substance. Lord Kelvin believes that it is quite true that the extraction of an electrion from the atom is opposed by a definite permanent force which must be overcome before the electrions can be drawn out. He computes the order of such a force.

Between electrodes $\frac{1}{48}$ of a mm. apart raised to a difference of potential of 200,000 volts the electrostatic force between them will amount to 96,000,000 volts per cm. and would give a force of $109 \cdot 10^{-6}$ dynes or 16·6 tons per sq. cm. in the electrostatic field; four times the above electrostatic force, or 1,280,000 C. G. S. units, would give a force of 66·4 tons weight per cm. The breaking weight of the strongest steel wire scarcely amounts to 20 tons per sq. cm. Hence the metallic electrodes under consideration would be broken into fragments. It would, however, bear the 96,000,000 volts or 16·6 tons per sq. cm.

Lord Kelvin believes it would be very desirable that careful experiments should be made with steady current on the highest obtainable vacuna.—*Phil. Mag.*, Oct. 1904, pp. 534–538. J. T.

13. *Slow Transformation Products of Radium.*—Professor Rutherford summarizes the successive changes of the various emanations and constituents of radium and finds that certain suppostitious products of pitchblende which he calls radium D and E should have very interesting rates of transformation. Radius D

should emit only β and γ rays. The β rays should decay to half value in about forty years. The radium E should emit only α rays and its value should fall to half value in about one year. Professor Rutherford considers whether these two products have been identified by various observers.—*Phil. Mag.*, Nov. 1904, pp. 636–650. J. T.

14. *Text-book of General Physics for High Schools and Colleges;* by JOSEPH S. AMES. PH.D. 768 pp.(American Book Company.) —In this extensive book there are many excellencies at once apparent to a reviewer. The print is all that could be desired and the diagrams are not only clear but, as a rule, exceptionally well designed. So too the pictures, which are presented in ample but not excessive numbers, are good and well chosen. An excellent feature, also, is the short bibliographies at the ends of many of the sections, which may prove especially helpful to a reader remote from a large library.

If we look for a distinguishing characteristic in this work with respect to its predecessors in the same field, we should doubtless find it an unusually frank effort to teach physics by a mere extension of the individual experience of the student. As this is a method which, to many teachers, seems beset with formidable difficulties, one turns with natural interest to the treatment of mechanics, here extended beyond the usual proportion. The definition of Mechanics (p. 33) takes the unusual form "the science of the inertia of matter." Nowhere, however, does the term inertia appear to be defined or used in a quantitative sense. The only definition (p. 14) is given in the following words : "If the motion of a body is changed in any way by means of our muscles, we are conscious of the sensation of force ; and the name 'inertia' is given to that property of the body owing to which this is trne." Mass is defined (p. 60) as pure number, consequently force is (p. 60) asserted to be a magnitude of the same kind as acceleration. Such inconsistencies, however, will doubtless be eliminated in revision. C. S. H.

I. GEOLOGY AND NATURAL HISTORY.

1. *The Stratigraphy and Paleontology of the Niagara of Northern Indiana.* Stratigraphy, by E. M. KINDLE : Paleontology, by E. M. KINDLE and C. L. BREGER. Twenty-eighth Annual Report of the Geological Survey of Indiana, 1904, pp. 397–486, pls. 1–25.—This small but important work treats of an area in which detailed stratigraphic and paleontologic work is very desirable because of the present great interest in the Cincinnati axis in relation to the distribution of Silurian faunas.

The Niagaran formations of northern Indiana are very largely covered by drift, so that no complete sections are shown. Well-borings indicate that the thickness for the entire Niagaran limestones, principally magnesian, varies between 250 and 500 feet. Proximity to land is indicated by the considerable variation in

short distances in the texture and composition of the limestones. Further, "local lenses of sandstone have been observed at some localities." In the Niagaran formation of northern Indiana, there is "a notable exception to the nearly horizontal and undisturbed condition which generally characterizes most of the other formations of Indiana." In the upper Wabash valley, "the strata are frequently found to be highly inclined." The dips vary from 5° to 80°.

"The general structure of the Niagara beds of northern Indiana is that of a broad arch with gently sloping sides trending northwest and southeast. It represents a northwestern extension of the Cincinnati geanticline. Its axis, approximately located, enters the state near Richmond, and passes northwesterly in the vicinity of Muncie, Marion and Peru, and continues north of the Wabash through Cass, White, Jasper and Newton counties into Illinois. On the two sides of this line of maximum elevation of the Niagara the Devonian and Carboniferous rocks dip in opposite directions; in Michigan and Ohio, toward the north and northeast; in Indiana, toward the southwest or south" (p. 409). "The arch described above is not the 'Wabash Arch' of Gorby, which apparently was supposed by its author to follow the Wabash Valley in eastern Indiana" (p. 409). "The dips seem everywhere to be quaquaversal, and it is believed that all of the tilted Niagara beds of northern Indiana represent small domes similar to those at Huntington and Wabash" (p. 411). "There is at present no positive evidence as to the nature of the forces which produced the domes. It seems probable, however, that they may be analogous in origin to the 'mud lumps' at the mouth of the Mississippi" as recently described by Harris.

"Whatever the causes may have been which produced the domes, there is clear evidence that they were developed about the close of the Niagara period. Many of them were elevated above the Paleozoic sea, while others probably did not reach its surface. Some of the domes remained above sea level during a considerable portion of the Devonian age, and there is some evidence that others continued as islands to the end of Devonian time."

"The occurrence of outliers of Pottsville conglomerate in the center of the Niagara area of northwestern Indiana near Remington and Jasper indicate that a subsidence occurred after the formation of the Niagara domes which submerged all or nearly all of the Niagara area of that region beneath the Carboniferous sea. The development of the present Niagara arch in northwestern Indiana was, therefore, of much later date and independent of the formation of the Niagara domes. While the domes date back to the end of the Niagara, the Niagara arch is of Carboniferous or post-Carboniferous age."

"The evidence at hand points to a general elevation of the sea bottoms at the close of the Niagara [Guelph] in the area around the northern end of the Cincinnati geanticline."

"A study of the faunas of the region has shown the presence in

it of faunas representing two distinct and successive epochs of the Niagara group." The earlier of these faunas is "correlated with that of the Lockport limestone of New York. The later fauna which has been recognized contains many species of the Guelph limestone fauna of Canada, which has not hitherto been known to occur in Indiana." The lower beds are called the "Noblesville dolomite" because no trace of the Guelph fauna appears in it.

The higher formation is named the Huntington. "The bulk of this fauna consists of a congeries of cephalopod and gasteropod species, mostly of large size, together with a few heavy-shelled brachiopods. Only four of the fifty species of brachiopods which occur in the Noblesville rocks of northern Indiana have been recognized in the collections from Huntington."

Discussion by the Reviewer.—As stated by Kindle, the Niagaran deposits of northern Indiana include two well-marked horizons equivalent to the Lockport and Guelph formations of New York. Clarke has recently shown that the Lockport limestone has in its upper portion a true Guelph fauna ; hence it may be said that in a general way the Noblesville and Huntington formations are equivalent to the Lockport and probably all of the Lockport of New York and the Guelph of Ontario. The Noblesville fauna is in the main made up of brachiopods, while the Huntington is essentially a gasteropod and cephalopod fauna.

Another important fact is indicated but not stated by Kindle. This is the absence of the Waterlime horizon in northern Indiana, although it is present over a great length of the state of Ohio. It is true that Waterlime is reported about Kokomo, Indiana, but the eurypterids from here are, with one exception, not those of the Waterlime, either of New York or Ohio. Further, *Conchidium colletti* of Kokomo is of the generic type abundant in the Noblesville, and in no other American place is this genus known above the Guelph. The occurrence here also of a *Wilsonia* (*W. kokomoensis*) is further suggestive of Noblesville. The conclusion seems warranted that the Kokomo cement beds are probably of Noblesville age rather than of the Huntington and especially the Waterlime or Bertie of New York. This conclusion finds further support in the fact that nowhere south of northern Indiana along the western side of the Cincinnati geanticline are known strata having a Guelph fauna. The work of Foerste in southern Indiana, Kentucky, and Tennessee indicates that the Silurian closed with beds not younger than the Lockport. All of Indiana was land from the close of the Guelph to the beginning of Onondaga time. In other words, during this time there was deposited in eastern New York all of the Cayugan, Helderbergian, and Oriskanian—a time of consideration duration. The first succeeding subsidence began in the south (Tennessee), for the Silurian is overlain by Helderbergian rocks of New Scotland age. In the north, subsidence did not take place until just before Onondaga time, since the oldest Devonian strata are of latest Oriskanian age (Decew-

ville) as may be seen about Decewville, Ontario. This subsidence was gradual and came in from the east and southeast, while the other progressed northward through the Mississippi embayment. With the beginning of Onondaga time, submergence was rapid and quite general throughout the Mississippian sea. It should be stated here that while the sea on the west of the Cincinnati axis became extinct at the close of the Guelph, on the east in Ohio it continues well into the Cayugan, as is proved by the presence here of Waterlime beds of the age of the lower Manlius of New York.

A marked peculiarity of the Noblesville assemblage is the almost total absence of corals, although to the south about the Falls of Ohio, and again near the straits of Mackinac, they are present in great variety and abundance. With this exception, the northern Indiana Niagaran fauna is more decidedly that of southern Indiana about the Falls of Ohio than that of northern Illinois and Wisconsin. This is seen by the presence in the Wabash area of the southern forms *Anastrophia internascens, Conchidium littoni, C. unguiformis, Gypidula rœmeri, G. nucleus, Camarotœchia whitei* (= *C.* sp. undet. of K. and B.), *C. acinus, Wilsonia saffordi, Atrypa calvini, Spirifer foggi, S. radiatus, S. crispus simplex, Cyrtia myrtia*, and *Meristina rectirostris.* Of strictly northern species, there are in the Wabash area *Conchidium multicostatum, Spirifer nobilis, Amphicœlia neglecta, Lituites marshii, Illænus armatus, I. insignis, I. ioxus, Ceraurus niagarensis, Sphærexochus romingeri*, and *Dalmanites vigilans.* Nearly all of the latter are free forms, with greater powers of dissemination than the brachiopods. These facts seem to warrant the statement that the Wabash axis was already in existence during Noblesville time, and that while it was more or less of a barrier against the free intermigration of the northern and eastern and southern faunas, it was not a complete barrier. That it was not effective is further seen in the peculiar distribution of *Conchidium.* In the Louisville area during Lockport, or rather Louisville (= Noblesville), time we have *C. complanatus, C. crassiplica, C. exponeum. C. knappi, C. littoni, C. nysius, C. tenuicostatum*, and *C. unguiforme.* In central and northern Indiana, about the same time, there are *C. colletti, C. littoni*, and *C. multicostatum*, and, in Wisconsin, *C. crassiradiatum, C. greenei*, and *C. multicostatum.* During Guelph time, in the Wabash area, there are *C. laqueatum* and *C. trilobatum*, and in Wisconsin *C. occidentale.* *C. laqueatum* is related to *C. occidentale* of the eastern Guelph, while *C. trilobatum* is unique unless it proves to be a *Stricklandinia.* This indicates that none of the Noblesville *Conchidia* pass into the Huntington, but that the species found in the latter formation come from the eastern Guelph.

That the Wabash axis was in existence long previous to the Niagaran is seen in the distribution of the earlier faunas. The first marked difference in the Ordovician faunas as seen on the

two sides of the Cincinnati geanticline, and especially in connection with the Wabash axis, is in the Richmond faunas situated to the northwest of the latter axis about Wilmington, Illinois, and Delafield, Wisconsin, and that to the south, especially as seen about Madison, Indiana. It is true that these Richmond faunas have many species in common and it is probable that they are not synchronous, so that there may have been land in southern Indiana at the time when the higher Richmond appeared in northeastern Illinois. This may mean that no true axis or "parma" was in existence during Richmond time, but it does seem to show that the Wabash parma at least indicates the strike for the then highest land. During Silurian time, this parma was a bar to the northward spreading of the Clinton and probably, also, of the Waldron formation. In fact, all the post-Clinton Silurian faunas to the north of the Wabash and east of the Cincinnati parmas are, in facies, more decidedly that of New York, while those south and west of the same barriers have another relationship. The fact that all these faunas have species in common goes to show that the Wabash axis was not at all times a complete barrier to the intermigration of faunas or that the Cincinnati axis was crossed by the sea somewhere in Kentucky or Tennessee. The dissimilarities on the two sides of the Cincinnati axis indicate that the Wabash axis had some effect on the dissemination of the faunas.

In regard to some of the species described, it seems desirable to make a few statements. *Trimerella* sp. appears to be a *Monomorella*, because the platform is not excavated, as may be seen in the cast, not having the two cones so characteristic of the former genus. *Stropheodonta corrugata* has been recently studied by the writer in specimens from the Clinton of Pennsylvania, and these prove the species to be a *Rafinesquina*. *Pholidostrophia niagarensis* is probably a *Brachyprion*, as it has radiating striæ. *Orthis flabellites* Foerste is hardly the well-known shell formerly passing in America as *O. flabellulum*. It looks more like forms of the *O. davidsoni* type. *Eatonia goodlandensis* cannot be an *Eatonia* as it has a dorsal sinus, the reverse condition of this genus. It is probably a pentameroid of the genus *Parastrophia*. *Meristina princeps* is known to be a true *Meristella*, and cannot, therefore, be referred to *Meristina*. The Indiana shell seems to be related to *Meristina maria*, if the striæ mentioned are internal markings. CHARLES SCHUCHERT.

2. *Report on an Exploration of Ekwan River, Sutton Mill Lakes and part of the west coast of James Bay;* by D. B. DOWLING.—This is "Part F" of the fourteenth Annual Report of the Geological Survey of Canada. It is particularly interesting on account of the fauna described by Whiteaves. In the Sutton Mill Lakes region, the Cambrian is also exposed and is regarded by Dowling as of the same age as that on the east shore of Hudson Bay, described many years ago by Bell and Low. In the latter region, the quartz conglomerates, quartzites, and sand-

stones, with a heavy trap overflow, attain a thickness of about 2800 feet. "This great thickness is not found on the west side of the bay." In the Sutton Mills Lakes region, 90 feet of sandstones and slates are shown "capped by an extrusive trap showing a thickness of 150 feet." These rocks "present many features in common with those from the Animikie of Thunder Bay." No fossils are mentioned.

Overlying the Cambrian is "a flat-lying limestone, which forms a wide belt around the west shore of James Bay and along the southern shore of Hudson Bay. On the Albany River the upper part of the series is proved to be of Devonian age, and beneath, at a greater distance from the sea, Silurian limestones are exposed. These beds probably overlap any older ones that may be beneath, and rest directly on the Archæan." The Silurian dolomitic limestone "does not appear to be of any great amount, probably not over 20 feet." The geologic series is terminated by Post-Tertiary clays containing *Saxicava rugosa*, *Mya truncata*, *Macoma calcarea*, and *Cardium ciliatum.*

According to Whiteaves, the Silurian fauna consists of 55 species, of which 39 are specifically named, 26 being restricted to the James Bay region. The percentage of new species is therefore rather high, but not greater than one would expect from a region so widely separated from other known Silurian areas. The assemblage both of species and faunal facies is not that of the Rochester or lower Lockport, as none of the characteristic forms of these well-known faunas are present.

On the other hand, it is directly comparable with the Guelph of Ontario and the higher Niagaran dolomites of Illinois and Wisconsin. This is seen in *Pycnostylus guelphensis*, *P. elegans*, an almost total absence of the lower Niagaran corals, cystids, crinoids, and brachiopods, and in the prescence of 2 species of *Trimerella*, 1 *Salpingostoma*, 3 *Gyronema*, and 3 *Bronteus.* C. S.

3. *Zinc and Lead Deposits of Northern Arkansas*, etc. With a Section on the Determination and Correlation of Formations; by E. O. Ulrich. Prof. Paper, No. 24, U. S. Geol. Survey, 1904, pp. 90–113.*—Ulrich's contribution is important because it attempts to correlate the Paleozoic formations of northern Arkansas and southern Missouri with "a standard time scale of the Ohioan Province." By "Ohioan Province" the author means the eastern half of the Mississippian sea, and also objects to using the latter term for this province because the name Mississippian "has a fixed application to the Lower Carboniferous rocks of America." In northern Arkansas, the Paleozoic section consists of the equivalents in the Ordovician of the Oneonta, Shakopee, St. Peter, Lorraine, and Richmond; in the Silurian of the Clinton; in the Devonian of the Chemung, and in the Carboniferous of a complete sequence from the Kinderhook into the Pottsville, except that the Warsaw and Spergen Hill are absent. From this it is seen that great breaks in deposition occur in the Ordovician, and from the basal Silurian through to the Upper Devonian.

* See also p. 394 of the November number.

The Clinton fauna (St. Clair limestone) is interesting because it is of the type found on both sides of the Cincinnati axis, and not that of New York.

The chief interest of this work, however, lies in the Carboniferous formations. As stated above, the Mississippian section is nearly complete and continues into the lower portion of the Pennsylvanian of the Upper Carboniferous. The author's best results are found in his discussion of the "Upper Mississippian formations" and "Early Pennsylvanian formations." It is seen that he here restricts the well-known name "St. Louis" to the formation as found about the city of St. Louis, which does not include the Spergen Hill and Warsaw horizons, usually embraced under this term. The author states that the St. Louis, Spergen Hill, and Warsaw "are readily distinguishable lithologic units, two of them having a wide geographic distribution, and all three occupying definite and distinct positions in the stratigraphic column. Together they constitute a group for which the name Meramec, after the river of that name in Missouri, where all three divisions may be seen, is chosen."

It seems unfortunate that the rules of the U. S. Geological Survey do not permit the use of a term with two values, i. e., as a formation and as a group name. In any event, it would seem preferable that the old and long-established name "St. Louis" should be retained in its present text-book use, i. e., to embrace all the time between the top of the Keokuk and the base of the Chester. Had this been done, the present author's group terms would now be those of other writers; as it is, however, to be up to date, we shall have to write "Meramec" for the old and apparently somewhat indefinite term "St. Louis." We could have more easily adapted ourselves to Meramec as the terminal formation of the group St. Louis.

The Chester of older writers receives here a far greater extension, is elevated to a group term, and includes the St. Genevieve, Cypress, Tribune, and Birdsville formations. The two latter are here embraced under the old name "Kaskaskia" of Worthen, a term that in the past has often supplanted Hall's name "Chester." The Chester group of Arkansas teems with new species.

One of the peculiarities of the Pottsville fauna in Arkansas, or in the area south of Missouri island (here called Ozarkia), is the presence of *Pentremites.* Heretofore this genus was thought to have disappeared in America with the Chester, and stratigraphers have always placed great reliance on this supposed limitation. Its occurrence shows paleontologists how unsafe it is to make correlations depending on single species or genera. It is stated in a foot-note that this interesting fauna will soon be described by Dr. Girty. C. S.

4. *Monographie de l'Ile d'Anticosti* (*golfe Saint-Laurent*); by Dr. Joseph Schmitt. Published by A. Hermann, Paris, 1904, pp. i–vi, 1–367, 12 text-figures and a map.—Since 1896, M. Henri Menier of Paris, France, has been the owner of the island

of Anticosti, and detailed Dr. Joseph Schmitt as resident physician and naturalist. The work cited describes the local geography, history, meteorology, geology, paleontology, botany, zoology, anthropology, maladies of man and animals, agriculture, and resources. There is also a bibliography of the island, 19 pages in length.

The Ordovician and Silurian stratigraphy is described in considerable detail on pp. 65–99. The divisions as established by Richardson and Billings are here accepted. Many of the more important geological localities are shown in full-page half-tones, the best we have seen of that island. The list of fossils on pp. 100–128 gives the horizons and localities for each species, with occasional remarks on certain forms. The book does credit to the present owner of the island, and especially to its author, Dr. Schmitt. C. S.

5. *Handbuch der Mineralogie;* von Dr. CARL HINTZE. Erster Band, achte Lieferung. Pp. 1121–1280.—The eighth part of the first volume of Hintze's great work has recently appeared. It contains the closing portion of the sulphur compounds, ortho- and basic sulpho-salts, sulpharseniates, oxysulphides, etc., and the beginning of the oxides. The closing pages are devoted to the species quartz. The part now issued is the twentieth of the entire series, which was begun in 1889.

6. *Volcanic Pipes of Sutherland.* — In the annual report of the Geological Commission of the Cape of Good Hope for 1903, Mr. A. W. ROGERS and A. L. DUTOIT give an account of some circular patches and dike-like outcrops of igneous rocks near the village of Sutherland. These "pipes" resemble closely the Kimberly pipes in form and relation to the surrounding rock, and some of them contain breccia similar in character to the diamond-bearing blue-ground of Kimberly. Melilite-basalt occurs in close connection with them, filling some pipes and forming dike-like masses around them. A complete petrographic description is given of these rocks, and the following analysis of melilite-basalt, from the Spiegel River, was made by J. Lewis.

Analysis of melilite-basalt: SiO_2 36·15, TiO_2 2·30, Al_2O_3 15·18, Fe_2O_3 4·87, Cr_2O_3 ·10, FeO 9·11,* MnO ·33, CaO 11·40, MgO 13·63, BaO ·06, Na_2O 2·42, K_2O 1·81, P_2O_5 ·26, SO_3 ·49, H_2O on ignition 1·95, H_2O driven off below 110° C. ·37 = 100·43.

It will be remembered that Professor Carvill Lewis felt very confident that melilite rock was closely connected with the original form of the Kimberly blue-ground, and it seems probable that the Sutherland area presents some of the same geological characteristics as the Kimberly district.

7. *A Treatise on the British Freshwater Algæ;* by G. S. WEST; pp. xv + 372, with 166 text-figures. Cambridge, 1904 (The University Press).—The need of a modern account of the freshwater algæ has long been felt by English-speaking botanists,

* A little sulphide which would slightly increase the figure for ferrous iron is included. The sulphur present as sulphide is included in the SO_3.

and this need is admirably supplied by Professor West's handbook. On account of the wide distribution of most of the genera described, the book will be welcome in North America as well as in the British Isles. After a short introduction the author discusses the structural peculiarities of the algæ, the methods of multiplication and reproduction, the doctrine of polymorphism and the various theories of phylogeny. The greater part of the work, however, is filled with detailed descriptions of the British genera and of the higher subdivisions, and under each genus the more important species are noted or briefly described. The characters derived from the peculiarities of the chloroplasts are emphasized throughout, and much attention is devoted to the species found in the plankton of lakes and ponds. The clear and accurate figures, nearly all of which are original, add greatly to the value of the work. Professor West includes among the algæ the diatoms and the blue-greens, two groups which many recent writers place apart; he excludes, however, the dinoflagellates and the stoneworts. Six classes are recognized: Rhodophyceœ or red algæ (with 6 genera), Phæophyceæ or brown algæ (with 8 genera), Chlorophyceæ or green algæ (with 130 genera), Heterokontæ or yellow-green algæ (with 8 genera), Bacillarieæ or diatoms (with 37 genera) and Myxophyceæ or blue-green algæ (with 45 genera). The Heterokontæ include a number of forms usually placed among the Chlorophyceæ. A. W. E.

8. *A Monograph of the British Desmidiaceæ*; by W. West and G. S. West; Vol. I, pp. xxxvi+224; 24 colored plates. London, 1904 (printed for the Ray Society).—In the last general work on the British Desmids, published by M. C. Cooke in 1887, 290 species are described. At the present time nearly 700 species are known from the British Isles, and of this number 147 species are figured and described in the present volume. The introductory chapter is devoted to a general account of the desmids and discusses the cell-structure, the variation, the methods of locomotion, the various types of reproduction, the phylogeny and the geographical distribution. This is followed by an analytical key to the 31 known genera, all but 5 of which are British. The descriptions of genera and species which fill the remainder of the volume are unusually full and accurate, and the plate-figures, nearly all of which were drawn by the junior author, bring out clearly the protoplasmic features of the cells and also the peculiarities exhibited by the cell-walls. Under each species the authors note the full synonymy, the measurements of the cells, the known localities in the British Isles and the general geographical distribution; and it is worthy of note that more than half of the described species have already been reported from the United States. The following 12 genera are treated in this first volume: Gonatozygon (5 species), Genicularia (1 species), Spirotænia (14 species), Mesotænium (10 species), Cylindrocystis (6 species), Netrium (4 species), Penium (28 species), Roya (3 species), Closterium (60 species), Docidium (3 species), Pleurotænium (9 species), and Tetmemorus (4 species). A. W. E.

III. Miscellaneous Scientific Intelligence.

1. *The Cyclones of the Far East;* by Rev. José Algué, S. J., Director of the Philippine Weather Bureau, Manila Observatory. Second (revised) edition. Pp. 83 with fifty-four plates. Manila, 1904.—The first edition of this work was published in Spanish in 1897 and embodied the results obtained during the thirty years that had elapsed since the foundation of the Manila Observatory in 1865. The present edition, in the English language, has been enriched by the additional data accumulated since 1897, not only from the Philippines themselves, but also from the adjacent coasts of Asia. The whole work gives a full account of the nature and origin of cyclonic stones and the various meteorological phenomena accompanying them; it also discusses in detail the typhoons of the far East, or the Baguios as they are called by the natives of the Philippine islands. The intensity and destructive character of these great storms in the regions covered by this work give them a peculiar interest and importance, while the author's long study of them has enabled him to present the whole subject with admirable clearness and fullness. The work is at once interesting to the public at large, of high utility to the sailing master because of the many practical suggestions given for his guidance, and also valuable as a scientific contribution particularly because of the discussion of the data in regard to individual cyclones of remarkable character.

The publications of the Philippine Weather Bureau also include a series of monthly Bulletins of the usual scope prepared under the direction of the Director, José Algué: of these the numbers from January to April, 1904, have been recently received.

2. *A Select Bibliography of Chemistry, 1492–1902:* by Henry Carrington Bolton. Second Supplement, pp. 462 (Smithsonian Miscellaneous Collections, part of vol. xliv).—The Select Bibliography of Chemistry from 1492 to 1902, a work of the greatest value to chemists, carried out by the late Professor Bolton, was issued in 1893. A First Supplement, bringing the work down to 1897, was published in 1899, while this Second Supplement, covering the five years to the end of 1902, is now given to the public. Professor Bolton died in November, 1903 while the work was in press and the proof-reading and preparation of the index have been in the charge of Mr. Axel Moth of the New York Public Library.

3. *Kritische Studien über die Vorgänge der Autoxydation;* by C. Engler and J. Weissberg. Braunschweig, 1904 (Fr. Vieweg und Sohn).—This monograph of two hundred pages, dedicated to the memory of Christian Friedrich Schönbein, aims to present a critical review of the scattered literature on the phenomena of so-called auto-oxydation. The authors explain their theory of the nature of auto-oxidative processes. Various types of katalytic reactions are discussed; and the influence of accessory factors, such as acids, salts, heat, light, etc., is considered. In a concluding brief chapter on the rôle of oxygen in living organisms the possible function of the different recently described oxidases, the formation of organic peroxides and the action of katalases is emphasized. L. B. M.

INDEX TO VOLUME XVIII.*

* This Index contains the general heads, Botany, Chemistry (incl. chem. physics), Geology, Minerals, Obituary, Rocks, Zoology, and under each the titles of Articles referring thereto are mentioned.

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